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Nutritional and Economic Analysis of Small-Scale Agriculture in Imbaburra, Ecuador

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NUTRITIONAL AND ECONOMIC ANALYSIS OF SMALL-SCALE

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by

Jake Erickson

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ABSTRACT

Nutritional and Economic Analysis of Small-Scale Agriculture in Imbabura, Ecuador

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Last year over $130 billion were distributed to developing countries to help eradicate extreme hunger and poverty. A body of literature has emerged challenging the effectiveness of development aid. Economic interventions habitually pursue income maximization through projects that develop economies of scale, share technology and science improvements, facilitate access to capital, conduct best management practice insemination, and/or grant access to markets. The end goal of such interventions is usually to create the revenue stream to externally purchase items needed to overcome malnutrition factors.

The critical view of aid stems from the separation of initiatives that exists only to address a portion of the equation. Intervention projects normally aim to satisfy either the nutritional needs of a group, or advancing the economic stability, but not both. One of the many issues that may arise by narrowly focusing and creating an aid program is that although a group may be fed, they are not equipped to mitigate risks that will arise after project completion and thus continue or revert back to a malnourished state. A bridge is required to join the economic and nutritional interventions to create aid interventions that are sustainable past the point of donor separation.

Merging economic and nutrition interventions as pursued in this thesis required the first step to be the creation of economic information for a typical small-scale farm.

A comprehensive set of estimated cost and return (enterprise) budgets for small-scale agricultural crops that could be grown by the representative farm family used in this analysis was developed. Utilizing these enterprise budgets, a linear programming model, and nutritional information, such as is done in this study, could help in planning rural development interventions as the income maximization and least-cost diet models are integrated into one within the resource and management constraints of the representative small-scale farm.

(222 pages)

PUBLIC ABSTRACT

Nutritional and Economic Analysis of Small-Scale Agriculture in Imbabura, Ecuador

Intervention projects in the developing world normally aim to satisfy either the nutritional needs of a group, or advancing the economic stability, but not both. One of the many issues that may arise by narrowly focusing and creating an aid program is that although a group may be fed, they are not equipped to mitigate risks that will arise after project completion and thus continue or revert back to a malnourished state. A bridge is required to join the economic and nutritional programs to create aid interventions that are sustainable past the point of donor separation.

This paper proposes the creation of a linear program model to assess the effectiveness and sustainability of such intervention programs.

Investigating the effects of merging economic and nutrition interventions as pursued in this report required the first step to be the creation of economic information for a typical small-scale farm. The region of Cochas, Imbabura, Ecuador was selected as the study area in which data would be collected for a representative sample of production and living circumstances of a poor, rural, and small-scale farmer.

A comprehensive set of estimated cost and return (enterprise) budgets for small-scale agricultural crops that could be grown by the representative farm family used in this analysis was developed. This was accomplished via data collected in rural Ecuador by Jake Erickson, a Master’s student in the department of Applied Economics at Utah State University. Of the supervisory committee, daily interaction occurred with Dr. DeeVon

Bailey, project supervisor, and Dr. Ruby Ward, linear program specialist, whom were crucial in project completion.

Various scenarios of the linear program were run with variations to the selection of nutritional requirements, off-farm income, and allowing food purchases off the family farm. Each of these scenarios was pursued as they mimic circumstances in which families may struggle to exist within the developing world. The results of each run are compared across the set of results to help understand what assumptions need to exist to validate an intervention’s approach to improving the standard of living or nutrition of the world’s poor, rural, small-scale farmers.

This model is a preliminary attempt at assessing the sustainability of merging common intervention approaches and it should be recognized that further development is needed to create a more encompassing model. Utilizing enterprise budgets, a linear programming model, and nutritional information, such as is done in this study, can help in planning rural development interventions as the income maximization and least-cost diet models are integrated into one within the resource and management constraints of the representative small-scale farm.

DEDICATION

This thesis is dedicated to my advisors, Dr. DeeVon Bailey and Dr. Ruby Ward. I am deeply indebted to them. Without their help, I would not have come this far. Their knowledge, experience, and insights paved the way for the completion of my research. Thank you for believing in me.

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CHAPTER 1

INTRODUCTION

In 2005, the World Bank (WB) estimated that 985 million were living below the international poverty line as of 2004. The WB revised this number upward in 2008 saying that an additional 400 million people worldwide were actually living below the poverty line in 2008 than in 2004. These new numbers demonstrated that over the past 25 years global poverty has been more widespread than previously believed. In addition, the cost of living in the developing world is higher than previously estimated due to data revisions provided by the World Bank's Development Research Group.

In the light of this information, the WB's estimates of poverty in the developing world have increased since 1981 and the number of persons living in poverty continues to climb (WB, 2012). The full scope of global poverty has yet to be completely measured as many of the Middle East and North African countries do not report this information publicly. Even if accurate estimates of poverty could be made, lags in survey data availability would mean that new estimates would not yet reflect the potentially large impact on poor people of rising food and fuel prices experienced since 2005. One thing is certain, about 100 million more people were pushed into the ranks of the world's hungry in 2011 compared to 2010 due to increased world food prices (Vishwanath and Serajuddin, 2012).

The most current data indicate that nearly half the world's population lives on less than $2 per day. More than one billion people in the developing world live on less than $1 per day. There are currently at least 1.4 billion people in the world living in extreme poverty, and an estimated 75% of the world's poor and hungry live in rural areas and depend directly or indirectly on agriculture. This is based on the fact that over 80 percent of rural households farm to some extent (IFAD, 2011). These poor, rural farmers in the developing world typically farm very small plots of land. They are often disconnected from markets, producing rather largely for their own family's consumption and selling only a small share of their harvest.

Many development economists have taken the view that low prices for agricultural commodities conflict with poverty relief in developing countries. This is based on the idea that low-income nations generate a majority of their total economic output through agriculture. Consequently, when rising prices are mitigated by food aid programs the effect is a reduction in household income for these small-scale farmers who otherwise would have benefited from higher prices and likely expanded their production. Many of the poorest people in developing countries depend on agriculture and higher food prices would tend to reduce poverty for this part of the population (Aksoy and Hoekman, 2010).

Increases in world food prices, especially for staple foods (figures 1 - 3), have raised concerns about food security for poor households in the developing world. Food prices in international markets increased dramatically during 2007 and 2008. The FAO World Food Price Index rose from 100 in 1980 to 140 at the end of 2004, and reached a climax of 282 in 2008. Even more recently, the FAO Food Price Index continues with a high average of 216 points in September 2012 (figure 1.4) (FAO, 2012). Despite the normalization of domestic food price inflation, domestic food prices in developing countries remain 25 percent higher relative to non-food consumer prices than they were at the beginning of 2005 (WB, 2012).

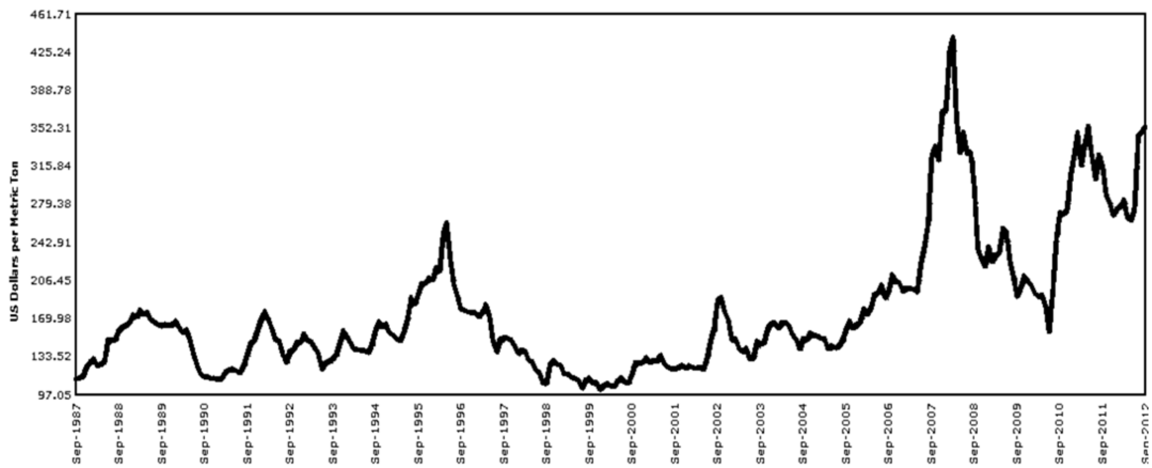
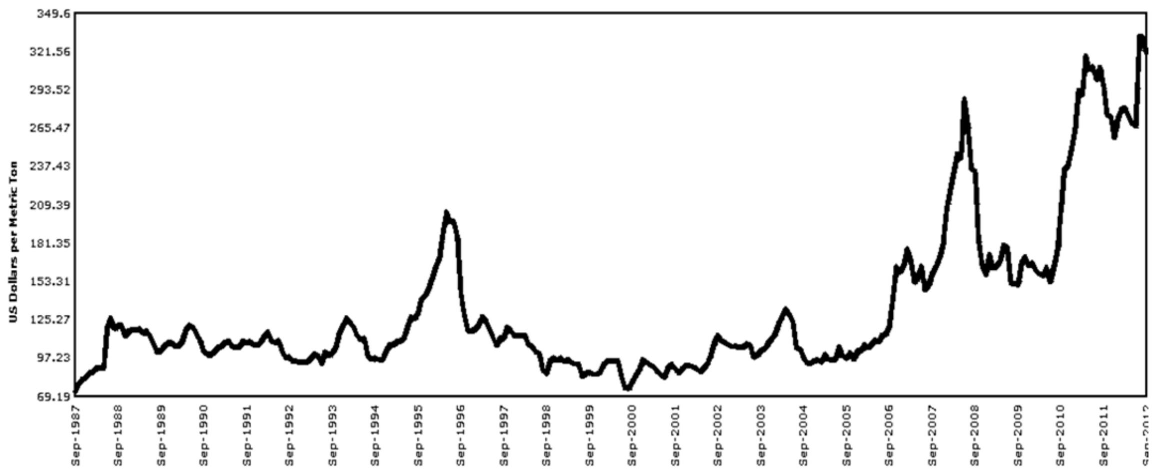


Figure 1. Wheat Monthly Price in US Dollars Per Metric Ton



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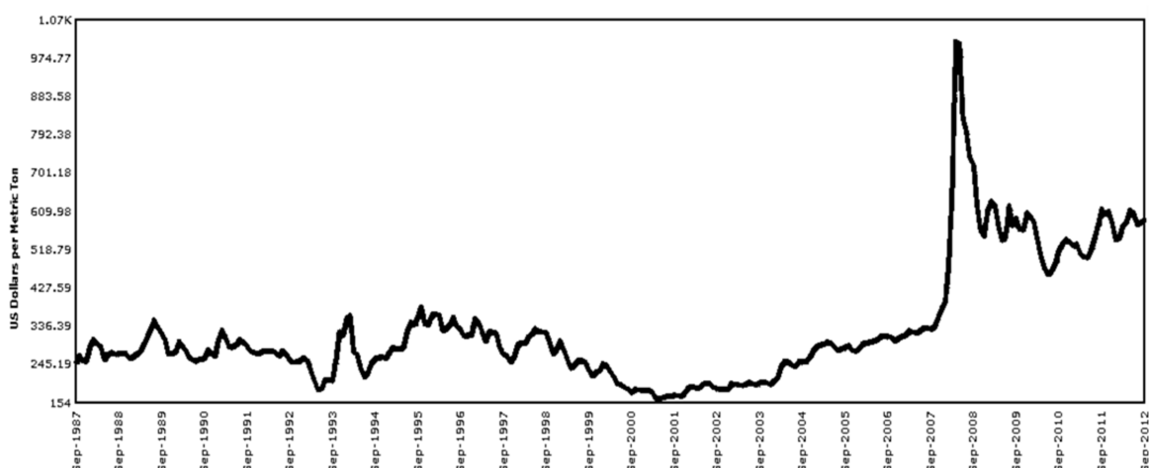

Figure 3. Rice Monthly Price in US Dollars Per Metric Ton

Source: Econ.World Bank.org, Commodity Price Data (a.k.a. Pink Sheet)

The organization and operation of rural and small-scale agriculture in the developing world requires new thinking if agriculture is to meet the needs of humanity now and in the future. The global community will need more than sustainable intensification, optimizing crop production per unit area, as production increases have not consistently improved food access for the world's poor (Kiers et al., 2008). The current focus of the developed world is not a form of sustainable intervention that the developing world needs. A new mindset needs to be established to better assist poor farmers in the developing world to meet basic nutrition and economic needs.

Developing countries often struggle to maintain political stability in the face of widespread poverty which breeds political discontent and corruption. Developing countries have sought the assistance of the developed world in helping to maintain political stability, internal security, and provide humanitarian aid through various forms of financial aid, food aid, education subsidies, and other types of interventions in the economies of developing nations. One example is the continent of Africa, whose countries receives a large portion of official development assistance (ODA); commonly referred to as "aid" (Figure 4). These countries often rely on interventions from the developed world to care for their needy citizens. The lack of infrastructure, capital, and educational opportunities provide significant barriers to capital formation and investment in general resulting in diminished opportunities, low income, low tax revenues, and often an inability for governments in the developing world to provide for some of the basic needs their people have such as security, health care, education, and the other government services and safety nets that are often taken for granted in the developed world.

Time Period	2007	2008	2009	2010
Receipient(s)				
All Developing Countries	$ 116,108.54	$ 146,582.43	$ 166,136.42	$ 168,101.23
Africa, Total	$ 38,935.27	$ 45,859.07	$ 52,431.01	$ 50,364.74
North & Central America, Total	$ 3,253.79	$ 6,627.62	$ 13,363.25	$ 15,785.77
South America, Total	$ 4,535.47	$ 7,651.51	$ 11,030.11	$ 9,666.88
Middle East, Total	$ 13,422.84	$ 20,085.03	$ 11,016.27	$ 9,137.97
South & Central Asia, Total	$ 18,327.28	$ 20,409.02	$ 23,923.18	$ 26,906.63
Far East Asia, Total	$ 7,341.49	$ 7,989.48	$ 10,837.87	$ 12,829.67
Europe, Total	$ 8,829.89	$ 11,179.25	$ 9,203.20	$ 9,885.11
Oceania, Total	$ 1,229.97	$ 1,664.46	$ 1,962.68	$ 2,856.64
LDCs, Total (Least Developed)	$ 33,344.42	$ 40,804.73	$ 41,980.76	$ 45,357.42
Developing Countries, Unspecified	$ 18,680.64	$ 22,304.34	$ 29,989.70	$ 28,405.30

Figure 4. Summary of Official Development Assistance Total Official Aid Flow Contributions in Millions of US Dollars

Source: Stats.oecd.org , Organization for Economic Co-operation and Development

It has generally been accepted that the developed world has self-interests in how the developing world develops and functions. This interest was primarily related to the resources that could be extracted from the developing world by developed countries during the colonial era. However, while the developing world remains an important source of raw materials for the worldwide economy, the interests of developed nations in the developing world have evolved as countries in the developing world gained their independence. Maizels and Nissanke (1984) reported that much of the political and economic rationale for developed countries providing bi-lateral aid to developing countries could be explained by the foreign policy agenda of the donor(i.e., political and security interests of the donor). However, Maizels and Nissanke (1984) also report that contributions by country donors to multi-lateral efforts in the developing world were explained primarily by specific needs, such as humanitarian needs, of the country receiving the aid (see also McKinlay and Little, 1977; Boschini and Olofsgard, 2001).

Others argue for the involvement of the developed world in the developing world based on moral obligation. For example, Singer (1972) presented the argument that those of the developed world, can and ought to do more for the developing nations. He expressed his disgust regarding the suffering caused by lack of food, shelter, and healthcare in the developing world. Singer (1972) professed that if the developed world can prevent one of these “bad” things from happening without sacrificing something of comparable moral importance, then the affluent people of the developed world are morally obligated to transfer large amounts of resources to the poor people in the developing world. Singer’s (1972) conclusion was that interventions need to be made by the developed world in the developing world to eradicate poverty of the poor until doing so harms the Developing World more than it benefits them.

The developed world has also provided immense amounts of aid to the developing world in the form of health (medical or nutrition) programs. While much of this type of intervention could be considered humanitarian, Howson, Fineberg, and Bloom (1998) point out that health risk cannot be adequately addressed within traditional national boundaries. They state:

> These risks include emerging infectious diseases, resulting in part from increased prevalence of drug-resistant pathogens; exposure to dangerous substances, such as contaminated foodstuffs, and banned and toxic substances; and violence, including chemical and bioterrorist attack. By investing in global health, industrialized countries will not only benefit populations in desperate and immediate need of assistance, but also themselves—through protecting their

people, improving their economies, and advancing their international interests. (p. 586)

Intervention often comes in forms of programs aimed at development and poverty reduction. Sustainability, democracy, capabilities, and woman's rights have all received immense attention in recent years, but interventions historically and currently are commonly manifested as humanitarian aid (e.g., food or health) or development assistance. For present purposes, consider humanitarian aid to be resources provided to relieve immediate suffering, and development assistance as resources provided in order to reduce an insufficiency over the long term. Health aid will be considered as medical and nutrition interventions including educational activities related to preventative care and improving nutrition.

A range of policies and programs exist to address household food insecurity and malnutrition at the local level.[1] The International Fund for Agricultural Development (IFAD) (2011)suggests that nutrition-based aid should address nutrition security by developing conditions that foster access to a stable supply of food. This narrow focus usually stems from undernutrition, nutrient deficiencies, and malnutrition. Undernutrition is one of the major problems in the developing world today. A large proportion of the world's population does not have enough food to lead healthy and productive lives. An even larger number of people is at risk of specific nutrient deficiencies because people are too poor to acquire foods containing essential vitamins and minerals. Malnutrition is the result from a complex set of interacting elements.

[1] Food security was defined by the World Food Summit in 1996 as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (World Health Organization, 2012).

These include but are not limited to cultural, social, biological, political, and economic environments. Thus the argument for different forms of economic intervention is created.

Economic interventions habitually pursue income maximization through projects that develop economies of scale, share technology and science improvements, facilitate access to capital, conduct best management practice insemination, and/or grant access to markets. The end goal of such interventions is usually to create the revenue stream to externally purchase items needed to overcome malnutrition factors.

Malnutrition cannot be overcome by solely improving access to an adequate diet. Infections, disease, poor maternal health, and child care practices may be as important a cause of malnutrition as is inadequate food intake (Unsystem.org, 1992). Therefore, although food aid by itself can make a significant contribution to relieving hunger, it cannot be expected to solve a complex problem such as malnutrition. It is when food aid is combined with other inputs, such as health care, education, improved agricultural technology and so on, that it can be most effective in overcoming poverty and malnutrition. This thesis assumes that economic and nutritional interventions need to be integrated to create a balanced model for aid that will be more sustainable.

A body of literature has emerged challenging the effectiveness of development aid. Much of this literature has been produced by people in the development and intervention community who care deeply about poverty reduction (Clement, 2011). The critical view of aid stems from the separation of initiatives that exists only to address a portion of the equation. Intervention projects normally aim to satisfy either the nutritional needs of a group, or advancing the economic stability, but not both. One of the many issues that may arise by narrowly focusing and creating an aid program is that although a group may be fed, they are not equipped to mitigate risks that will arise after project completion and thus continue or revert back to a malnourished state. A bridge is required to join the economic and nutritional interventions to create aid interventions that are sustainable past the point of donor separation.

Merging economic and nutrition interventions as pursued in this thesis required the first step to be the creation of economic information for a typical small-scale farm. The location of the farm was in northern Ecuador, but the basic analysis presented here could be adjusted and used in similar circumstances in any location in the developing world. A comprehensive set of estimated cost and return (enterprise) budgets for small-scale agricultural crops that could be grown by the representative farm family used in this analysis were developed. This produced a means for comparing crop data to estimate projected costs, revenue, and net returns for a single enterprise to assess feasibility and profitability of potential enterprises. These enterprise budgets could also be a planning tool to test out new ideas and compare enterprises to identify "best" ones as they permit a comparison of income across different enterprises. Utilizing these enterprise budgets, a linear programming model, and nutritional information, such as is done in this study, could help in planning rural development interventions as the income maximization and least-cost diet models are integrated into one within the resource and management constraints of the representative small-scale farm.

This model could develop assistance and interventions which consider a broader range of resources and constraints than analyses of isolated nutritional or economic interventions. The result could offer additional insights about how nutritional, economic, and agronomic interventions might act together to reduce poverty and increase health of the rural poor over the long term. The perpetual intergenerational cycle of poverty and hunger is interdependent and directly related to poor health, which translates into lack of readiness for school, which harbors poor academic performance, which then positions the individual to be inadequately prepared for economic opportunities. Supporting surveys and data sets used in this analysis are composed of information gathered from rural small scale subsistence farmers in the community of Cochas, within the Imbabura Province of Ecuador, South America.

CHAPTER 2

REVIEW OF THE LITERATURE

The objective of this study was to integrate economic, nutrition, and agronomic principles into a mathematical-programming, decision-making framework. The reason this is important is that so much effort and money are expended trying to help the world's rural poor, but are often targeted at specific interventions that do not take into full account the complex interactions of economics, nutrition, and agronomy that determine whether an intervention is sustainable or not. This chapter presents a review of the literature about different types of interventions designed to assist the rural poor, their rationale, contributions, and potential weaknesses. A case is then made for why an integrated approach makes a contribution to this literature.

Food Aid

Food aid is a difficult subject to summarize because of its intertwining themes. In general, food aid deals with providing food and related assistance to combat hunger. Principally food aid is designed for emergency situations (short-term interventions) or to help reduce severe hunger over the long term by achieving food security. Food security refers to the availability of food that an individual has access to while starvation is the severe deficiency in vitamin, nutrient, and caloric intake (FAO, 2012). In 1960, food aid constituted over 20 percent of all global aid flows in terms of dollar value but now it is less than five percent (WB, 2010). Although food aid has decreased, this does not signal that the problem of hunger is becoming less severe. Food aid is still important because of the prevalence of world hunger and the increase in food emergencies in the past decade

(WFP, 2007 and 2012). The decline of food aid as well as the way in which it is delivered and used, therefore remain very important.

Food aid as a modern policy measure had its start in the 1950s with the United States together with Canada accounting for over 90 percent of global food aid until the 1970s when the United Nations World Food Program (WFP) became a major player (Usaid.gov, 2012). International food aid is largely driven by donors and international institutions. In 1967, the Food Aid Convection (FAC) provided a set of policies for donor countries and is monitored by the Consultative Sub-Committee on Surplus Disposal (CSSD) (Foodaidconvention.org, 2010). The CSSD's primary purpose is to ensure that food aid does not affect commercial imports and local production recipient countries (FAO, 2001). In effect, the CSSD ensures food aid does not displace trade.

Food aid is typically separated into three groups to categorize the international flows that come in the form of food or cash to purchase food in support of food assistance programs. The three types are program, project, and emergency/humanitarian.

Emergency Food Aid

Emergency food aid, commonly referred also as relief aid, is typically for emergency situations, such as cases of war, conflict, or natural disaster. Deliveries of food are provided by a developed country (such as the United States or United Kingdom) to government and non-government agencies (GO and NGO) responding to crisis in an affected country or countries where the food is distributed without charge. However, a number of countries facing some forms of chronic food insecurity have also become permanent recipients of this form of aid (Mousseau, 2005).

Program Food Aid

Program aid often is a form of "in-kind aid" whereby food is grown in the donor country for distribution or sale abroad. This is typically a government-to-government transfer which includes deliveries of food to a central government that subsequently sells the food and uses the proceeds for whatever purpose (not necessarily food assistance). Rather than being free food as such, recipient countries typically purchase the food with money borrowed at lower than market interest rates (USDA, 2009). Program food aid provides budgetary and balance of payments relief for recipient governments.

Project Food Aid

Project aid provides support to field-based projects in a specific area of chronic need through deliveries of food, usually at no charge, to a GO or NGO that either uses it directly to promote agricultural or economic development or nutrition and food security, such as food for work and school feeding programs. At times, this type of food aid is monetized (sold at market value) to allow the organization to use the proceeds for project activities. Program and Project Food Aid makes up the majority of aid for the United States (USDA, 2012).

Shift in Policy and Purpose Relative to Food Aid

Emergency aid used to be a minor form of aid until the 1990's when it shifted to being the dominant form of aid provided by the U. S. to developing countries signifying both an increase in the number of food emergencies and the end of the Cold War (i.e., after the Cold War food aid as a political tool for the donor seemed to become less important) (Mousseau, 2005). As with relief aid, project food aid is typically distributed by the WFP, NGOs, and occasionally by government institutions (FAO, 2009).

The European Common Agricultural Policy (CAP), created in 1962, is geared towards increasing agricultural productivity and food self-sufficiency (European Commission, 2011). Through a combination of farm price supports and barriers to food imports, the CAP generated massive surpluses, especially wheat and animal products, which made the European Union (EU) and its member countries major actors in international food trade and food aid (European Farmers Coordination, 2003).

In the 1950s, the Food and Agriculture Organization of the United Nations (FAO) had warned of the potentially harmful effects of food aid on local agriculture (Oxfam, 2005). Cheap imports from developed countries, including through food aid, often undermines local agricultural production because it distorts the market and does not provide local farmers with the opportunity to receive higher prices and expand production when food supplies in a local area are tight. Food aid drives down food prices and encourages increased consumption of wheat and dairy. This, in turn, adversely affects the livelihoods of rural populations and drives the “non-competitive” local farmers out of agriculture.

As noted earlier, current food aid has seen some changes during the past decade. Europe, for example, has generally moved away from in-kind food aid, preferring to purchase locally in the affected country or help facilitate local purchases instead. There has also been a shift away from long-term development to short-term humanitarian relief. This has increased the role of NGOs and relief organizations and led to a prioritization by donors on nations that actually need assistance. This is partly in contrast to the past when food aid was often targeted towards countries that provided a strategic interest for the donor, i.e., a “friendly” nation during periods like the Cold War.

The EU has shifted towards local and "triangular" purchases. These are food aid purchases or exchanges in one developing country for use as food aid in another country. Many argue this type of food aid will lead to more efficient distribution of food and better support for agriculture, trade, and development in the developing nations. Frederic Mousseau (2005) of the Oakland Institute summarizes Europe's shift:

> The shift from the export of surpluses to more purchases from within southern countries has been strongly promoted by a number of NGOs and researchers over the last twenty years.… Overall, in 2004, 1.6 out of a total of 7.5 million tons of food aid was obtained through local or triangular purchases in developing countries. The EU officially adopted this policy standpoint in 1996 and adapted its food aid programs accordingly through a progressive increase in the share of cash assistance for triangular and local purchases and more attention for non-food interventions. As a result, a major share of EU food aid—90 percent in 2004—is now procured in developing countries (this figure is only approximately 1 percent for the US). (p. 11)

However, Europe is not functioning on a completely united front either. While the EU itself has made this policy modification, some nations such as Italy and France have lagged by maintaining a flow of in-kind food aid instead of the contractual path which represents nearly 70 percent of their food aid (Clay, 2006).

React, Rather than Prevent

Relief aid, by definition reacts to emergencies, rather than to prevent them. It is short-term aid, whereas going to the roots of hunger (e.g. poverty, debt) is more complicated and leads to problems such as the ones that have been previously discussed with program aid. Emergency food relief therefore goes to fixing disasters that could have been addressed much earlier with better policies. So both natural disasters, where emergency food aid is undoubtedly an appropriate and needed response, and human-made, preventable disasters compete for relief aid (Tearfund, 2005).

Whether organized by a GO or NGO, interventions in the developing world seem to follow the path outlined by the Millennium Development Goals (MDG) that the United Nations (UN) have set forth. The first goal (MDG 1) calls to eradicate extreme poverty and hunger and claims that this goal's achievement is crucial for national progress and development (UN, 2010). One of the ways that progress is assessed toward achieving MDG 1 is the prevalence of underweight children under the age of 5 (UNICEF, 2012a). Since the MDGs were adopted in 2000, an improved knowledge of the causes and consequences of under nutrition has been achieved. Reducing the rate of underweight children depends on the correct design and subsequent implementation of large-scale nutrition and health programs that provide appropriate food and health care for children in a country (Vander Meulen and Mucha, 2012). Failure to realize MDG 1 endangers the achievement of the other MDGs which include improving maternal health, reducing child mortality, and achieving universal primary education (UN, 2010).

Nutrition

Healthy eating and being physically active are particularly important for children and adolescents. This is because the nutrition and lifestyle of children influence their wellbeing, growth, development, and general health throughout their lives. The nutritional requirements of children and adolescents are high in relation to their size because of the nutritional demands for growth for children beyond that needed for body maintenance and physical activity (WHO, 2008). Recent evidence makes it clear that children under the age of five are in the period of high vulnerability to nutritional deficiencies. Specifically, the period beginning with the woman pregnancy and continuing till the child is two is when children are at their greatest vulnerability in terms of the effects of malnutrition. It is during this period that nutritional deficiencies have the greatest impact on child survival and growth (Engle et al., 2007; UNICEF, 2012a).

Nutritional deficiencies over a period of time lead to diminished or stunted growth. In the developing world there is a high degree of nutritional stunting, defined as linear growth failure caused by inadequate caloric intake. Stunting may be intensified by various infections accompanied by malnutrition (Deboer et al., 2012). Once children are stunted it is difficult for them to achieve average height, as stunting is considered “the irreversible outcome of chronic nutritional deficiency during the first one thousand days of a child’s life” (Unicefchina.org, 2012).

The global burden of stunting is far greater than the burden of children who are underweight. UNICEF shows that in the developing world, the number of children under five years old who are stunted is close to 200 million. The children under five years and underweight are about 130 million (Unicef.org, 2009). Specifically, undernutrition in early life for girls before they give birth or during early childhood can have perpetual effects because their future babies are likely to be born with low birth weight which then leads to undernutrition as those children grow (Langley-Evans, A. and Langley-Evans, S. 2003). This creates a vicious cycle of under nutrition repeating itself generation after generation due to heritable changes in gene expression (Schoendorfer et al., 2010). Developmental origins of health problems and disease suggest that developing fetuses and potentially young children undergo adaptive epigenetic[2] changes that have longstanding effects on metabolism and other processes (Deboer et al., 2012). Addressing nutritional deficiencies and taking appropriate means to prevent and treat such deficiencies is therefore imperative.

Chronic undernutrition in early childhood also results in diminished cognitive development, in addition to the diminished physical development, which puts children at a disadvantage for the rest of their lives (Schoendorfer et al., 2010). Nutrition plays a key role in cognitive development as cognitive development starts in the fetal stage and continues beyond with the largest amount of cognitive growth happening during the fetal stage (Benton, 2010; Paus, 2010). Undernourished children historically perform poorly at school, and as adults, may be less productive, thus increasing the chance of earning a lower wage while facing a higher risk to disease than those adults who are not undernourished as children (Save the Children, 2012).

It is recognized that good nutrition is of crucial importance for the wellbeing, growth, and development of children. Growth rate is a sensitive indicator of overall dietary adequacy (Butte, 2000). Growth rates depend strongly on nutrition during early childhood. Because growth may not be a completely accurate manifestation of well-being, five major nutritional components should be considered: energy, macronutrients, fluids and electrolytes, micronutrients, and calcium/vitamin D (Foster et al., 2012). If children do not receive adequate nutrition up to their second birthday, they could suffer irreparable physical and cognitive damage. Undernourishment also lowers disease resistance. The consequences of poor nutrition can continue into adulthood.

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[2] The U.S. Library of Medicine has defined epigenetic as relating to, being, or involving a modification in gene expression that is independent of the DNA sequence of a gene

Associations between childhood malnutrition, early-life infections, and the increased occurrence of other risk factors underscore further reasons to improve nutrition and infection-related outcomes for young children worldwide (Deboer et al.,2012).

Disease

The primary cause of death and morbidity in developing countries, particularly in children, is infectious disease (Fong, 2000; Bourne et al., 2007; WHO, 2011b). Increasing evidence suggests that malnutrition is the underlying reason for increased susceptibility to infections (Ambrus Sr., J. and Ambrus Jr., J., 2004). On the other hand, certain infectious diseases also cause malnutrition, which results in a vicious cycle. Before its viral origin was known, acquired immunodeficiency syndrome (AIDS) had been termed the thin disease because wasting syndrome was AIDS' main clinical manifestation. The relationship between infection and malnutrition is well documented in the literature.

An example of a disease that still exists is the developing world is schistosomiasis, also known as snail fever. This disease is caused by parasitic worms. Although the worms that cause schistosomiasis are not found in the United States, more than 240 million people are infected worldwide. In terms of impact this disease is second only to malaria as the most devastating parasitic disease (Cdc.gov, 2012; WHO, 2012a). Once infected and if not treated, the symptoms develop as abdominal pain, enlarged liver, blood in the stool or blood in the urine, and problems passing urine. Chronic infection can also lead to increased risk of bladder cancer and eggs found in the brain or spinal cord that can cause seizures, paralysis, or spinal cord inflammation (Cdc.gov, 2012).

In developing countries, undernutrition leads to increased risk of mortality due to infections. One-third of all deaths in children under the age of five are due to infections, namely diarrhea and pneumonia. Young children continue to suffer morbidity and mortality from infectious disease at an unnecessarily high rate while chronic disease is taking a hold of the adult population. Those that do survive are more likely to contract chronic diseases (Barker, 1990; Almond et al., 2011). Others that survive do so with adaptive physiological changes such as reduced body size (stunting) or altered kidney morphology (Mesquita et al., 2010).

Chronic diseases in adulthood have origins in the fetal and early postnatal period. The fetal programming hypothesis states that the structure, function of organs, and tissues are "programmed" or permanently altered in ways that predispose individuals to chronic disease later in life in response to undernutrition during critical periods of growth and development (Adair, 2002). In areas with poor sanitation, children experience vicious cycles of enteric[3] infections and malnutrition, resulting in poor nutrient absorption as a result of changes in the intestinal mucosa, now termed "environmental enteropathy" (Korpe and Petri, 2012).

To summarize, the poor predominantly die of infectious diseases: lung infections, diarrheal diseases, HIV/AIDS, tuberculosis, and malaria (WFP, 2007). Complications of pregnancy and childbirth together continue to be leading causes of death by claiming the lives of both infants and mothers (Fang et al., 2012). Research indicates that it is most critical to address nutritional and health needs of mothers and children from birth to age

[3] Enteric – a disease of the intestines caused by an infection that effects intestinal absorption

two. If the children do not receive adequate nutrition up to their second birthday, they could suffer irreparable damage that lowers disease resistance (Geoghegan et al., 2012). The consequences of hunger and poor nutrition can and do continue into adulthood.

Economic Considerations Relative to the Rural Poor

A common theme exists suggesting that solving world hunger will be achieved via some method that will produce more food. Often missed is the relationship between poverty and hunger. Tackling hunger directly by providing more charitable contributions of food, or even finding ways to increase production, is attacking the symptoms of poverty only, not root causes. Solving world hunger in the conventional sense of providing/growing more food will not tackle the poverty which leads to hunger in the first place.

In an effort to combat hunger, donors provide food aid. Food aid (when not for emergency relief) can actually be very destructive on the economy of the recipient nation and contribute to more hunger and poverty in the long term (Barrett, 2006). Free, subsidized, or inexpensive food below market prices undercuts local farmers who cannot compete and are driven out of jobs and into poverty (Oxfam, 2005). This further slants the market share of the producers in the developed world. Many poor nations are dependent on farming, and so such food aid amounts to food dumping in the local economies. In the past few decades, more powerful nations have been criticized as using this as a foreign policy tool for dominance rather than for real aid (Oxfam, 2005; Mourmouras and Rangazas, 2007; Brautigam, 2009). While providing solutions to hunger by way of more efficient food production seems to be the correct attempt, the real problems lie in distribution, land ownership, inefficient use of land, and politics with its accompanying power plays.

There are important issues with the identification of the poor and how they survive. First, computing the poverty line utilizes purchasing power parity exchange rates which have been criticized as being inadequate, infrequently updated, and inapplicable to the consumption of the extremely poor (Deaton, 2006). Coupled with incomplete data collection and reporting within the developing world, it is challenging to properly define and measure this subset of the global population. It is certain though that the percentage living in poverty is growing and is faced with insurmountable food prices.

Food prices are typically considered to be higher in urban than rural areas. A further review indicates that in rural areas, the poor may pay different prices than everyone else (typically higher) due to the lack of competition. Subsequently, families that depend on small-scale agriculture are at a greater disadvantage than those who are not as the prices paid for inputs and later received in payment for crops are commonly not at the “going rate”. The small-scale farmer pays more for inputs and does not receive full farm-gate price when it is time to sell the harvest (Banderjee and Duflo, 2006).

Structural Adjustment Programs (SAP) have been implemented in most developing countries over the past two decades. They have generally led to the elimination of public intervention in the agricultural sector, including state-led institutions such as marketing boards, which in the past supported small-scale farmers through credit, inputs, and facilitation of market access (WHO, 2012b). SAPs have also encouraged the concentration of agricultural trade and production, which excludes small-scale farmers from business and growth (Mousseau, 2005).

In a small restricted market, price and yield tend to offset one another. The smaller the local harvest, the greater the price per unit received and vice versa since supply and demand are largely determined by the harvest itself. Within a world market however, this nexus between local harvest and price is broken and the world price varies more or less independently of local supply (Scott, 1976). Accepting that the world operates on a competitive market, the farmers in developing countries are producing in a global market and thus must compete with all the other farmers in the world to produce and sell their crop. Producers in a competitive market cannot control price so they must produce at or below market price to remain in business in the long run. Generally, any cost advantage small-scale agriculture in developing countries have is through labor costs (Ward and Bailey, 2012). Farmers and supporting agricultural laborers work for very small amounts of money. One major disadvantage small-scale farmers compared to larger-scale farmers have is scale. Small-scale limits access to capital purchases and achieving economies needed for discounts and sales. This implies that the labor advantage of small-scale farmers in the developing world is their competitive edge. The problem is that labor prices are rising in some parts of the developed world such as China and India suggesting that this advantage may be shrinking except for the poorest of the poor (Sharma, 2009).

The area of the world that receives the most attention regarding the existence of hunger and related aid is Africa. Until the food price alarm went off in recent years, discussions on how to reduce hunger and malnutrition in Africa took place in an environment of declining food prices with estimates indicating that real food prices declined by about 75 percent between 1974 and 2005 (Economist, 2007). Since then, strong upward trends in global food prices occurred in 2007–2008, in late-2010, and again in mid-2012 (figure 5). This created the concern that hunger and poverty will increase across the world as the access to affordable food to the poor is reduced. People are hungry not due to lack of availability of food or the ability to produce food worldwide, but because people do not have high enough income to purchase the nutritious food they need and because distribution of food is not equitable. In addition, politics also influence how food is produced, who it is produced by with subsequent benefits, and for what purposes the food is produced; such as for exporting rather than for the hungry and feedstuffs within a food-deficit country.

Figure 5. FAO Nominal and Real Food Price Index

If efforts are only directed at providing food, or improving food production or distribution, then the structural root causes that create hunger, poverty and dependency, would still remain. This is not to say that research aimed at increasing food production should not be done, it is to illustrate that attacking the roots of poverty that cause hunger would allow better use of resources in the long term. Not fighting root causes of poverty and only fighting hunger will be costly in the long run as people will continue to be hungry and resources will be continually diverted to remedy hunger in a superficial manner without addressing its cause. Agricultural sectors need to be provided with the right investments and incentives to produce sufficient food and lay the basis for broad-based and sustainable economic growth.

The Need for Interventions

Poverty traps call for external intervention because no spontaneous mechanism exists to stop the eternal round of poverty. Several contributory factors such as poverty, lack of purchasing power, household food insecurity, and limited general knowledge about appropriate nutritional practices increase the risk of individuals in developing countries. External support in either government or non-government forms can help alleviate the physical and economic challenges that the world's poor confront on a daily basis. Many different interventions have been created to help the suffering populations of the world secure a better quality of life while trying to disrupt the vicious cycle that accounts for the high mortality and morbidity rate in these countries. Some of the interventions and reasons they are implemented are:

- Vaccinations- to help control disease/infection
- Supplements- to help provide the nutrients needed for healthy growth and support the immune system to reduce infection
- Sanitation- eliminate disease and infection through controllable aspects of life
- Micronutrient/Macronutrient Crops- provide a source to create a balanced diet, least cost ration
- Education- provide individuals with learning to succeed
- Storage- provide food security
- Cash Cropping- create cash flow
- Marketing- create access to markets
- Technology and Science- allow farmers to better compete, be efficient with time

- Best Management Practices- insemination best management practices by way of classroom lessons and on farm teaching

This study serves to review a portion of the more dominant aid and intervention programs that have been implemented and are summarized into the sections of 1) Health, 2) Farm, and 3) Finance.

Health

Interventions designed to improve health are in effect designed to improve the quality of life of those who participate. Health interventions have multiplier effects as they contribute to “sustained population and economic gains in poor countries” (Bhalotra and Pogge, 2012). As morbidity and mortality decrease, mothers tend to have fewer births as offspring and potential offspring become more likely to survive. This lowers the growth of population while contributing to a greater economic growth (Galor and Weil, 2000). To reduce morbidity and mortality, the most prolific interventions are sanitation programs, vaccines/immunizations, and supplements.

Sanitation

Creating a clean environment can reduce exposure to infectious disease. In the developing world, many health problems are directly related to fecal-oral contact by food or water (Cairncross, 2003). Cholera, e-coli, hepatitis A, rotavirus, giardia, and tapeworm are common infections contracted and spread through poor sanitation (Gerba et al., 2009). To insure a greater level of sanitation, interventions provide disinfectant hand rub, latrine construction, teach hand washing practices, point of use water filtration, and also provide water access projects such as drinking water wells (Rodgers et al., 2007; Allegranzi et al., 2010; Ngondi et al., 2010; Kaewchana et al., 2012).

Vaccines

The World Health Organization claims that 2-3 million deaths are averted annually by vaccination. Yet, only 20 percent of children who need antibiotics receive them (WHO, 2010a). Whether it be the developed world or the developing, the evidence is clear about the need for vaccines and immunizations to prevent many diseases. Within the literature, the terms immunization and vaccine are used interchangeably even though in the medical profession there is a specific use and definition for each of these terms (Dorlands.com, 2012).

Strong evidence exists that interventions using vaccinations are an effective means to assist in lifting the world's poor from poverty. One trial involving de-worming in Kenyan schools estimates that treatment generated 2–3 additional years of schooling and a 21–29% increase in income (Baird et al., 2011). Other studies using cohort data on large-scale historical interventions arrive at remarkably similar estimates. A retrospective analysis estimates that malaria eradication in the Americas increased wage income by 15–27 percent (Bleakley, 2010). Immunization programs within developing countries have been shown to decrease disease transfer creating better health within households and communities, thus fostering economic growth (Bhalotra and Rawlings, 2012). Although vaccine interventions may come with relatively high costs, the cost benefit analysis shows returns anywhere from .59 to over 22 times the savings for every unit invested in vaccines and immunizations (Bloom et al., 2005). The benefits produced by vaccine interventions are estimated to be even greater over the span of a generation (Bhalotra and Rawlings, 2010). The continued push for vaccination-based interventions is centered on the fact that infectious diseases can only be eliminated if high levels of vaccination are achieved and maintained (Campbell, 2006)

Supplementation and Fortification

In 1989, Stephen DeFelice coined the term and defined nutraceutical as any substance that is a food or a part of food that provides medical or health benefits, including the prevention and/or treatment of disease (Nutraceuticals World, 2011). The generally accepted terms within the world of nutrition are supplementation and fortification (SF). Such products may be categorized as dietary supplements, specific diets, herbal products, or processed foods such as cereals, soups, and beverages. Dietary supplements can be extracts or concentrates and are found in many forms, including tablets, capsules, liquids, and powders. Vitamins, minerals, herbs, or isolated bioactive compounds are only a few examples of dietary ingredients in the products. Functional foods are designed as enriched foods close to their natural state, providing an alternative to dietary supplements manufactured in liquid or capsule form (Adelaja and Schilling, 1999; Whitman, 2001; Azizi, 2012). Generally, the SFs used in developing countries are in pill or liquid form.

Supplements are a popular form of a supplementation program to help achieve better nutrition because of the minimal cost, often $1 or less per individual per year, associated with treating nutritional deficiencies (Chow et al., 2010; Hki.org, 2008). Vitamins such as vitamin C, vitamin E, and vitamin A are the common forms of supplements (Clark et al., 2008; Hki.org, 2011). However, there are many SFs and even more interventions that employ the use of them. This is based on previous studies which show the improved benefits to health resulting from taking these supplements. It should be noted that SF interventions are not always based on previous studies completed about SFs benefits specific to individual antioxidant nutrients (Sun, 2005). Interventions are often based on studies of the foods rich in these nutrients and related benefits (Chao et al., 2012).

Continued support for SFs is created as more studies of previous interventions prove they have been successful in achieving nutritional goals for the poor. Between 1969 and 1977, one intervention supplied protein shakes with other micronutrients to persons in four villages in Guatemala (Habicht et al., 1995). Thirty years later, the International Food Policy Research Institute (IFPRI) conducted a study to investigate the long-term effects of the supplied nutraceutical. The study found that participants of the original intervention did not suffer growth failure, completed more schooling, scored higher on cognitive skill tests, and earned higher wages than others not receiving the supplements. Specifically, the results for women participants were they had fewer pregnancies, and lower risk of miscarriages and stillbirths (Hoddinott et al., 2011).

Although supplements are shown to be beneficial, governments are recognizing that these types of programs are not sustainable. They are turning to food crops to solve the issues that the concentrated forms of macro and micro nutrients have not been able to sufficiently address. Examples include Bangladesh and the Philippines who have joined the cause of Golden Rice (Irri.org, 2011). Most famous for its failure due to its intense orange color resulting from it having 23 times more beta carotene than “normal” rice, Golden Rice is seen as a sustainable solution to providing millions with adequate intake of vitamin A (Mayer, 2005). India has recognized that the previous decades of vitamin A supplementation programs have not been effective on a large enough scale. As a result, India has begun to stress that the avenue to prevent deficiency should be through better food rather than with pills (Palmer and West, 2010; Indianexpress, 2012; UNICEF, 2012b).

Helen Keller International (HKI) is a leading global health organization that has been instrumental in reducing vitamin A deficiency in the developing world. HKI's first effort toward blindness prevention and treatment was the distribution of vitamin A capsules in the Asia-Pacific area and Central America in 1960-1970. Since then HKI has expounded its effort for achieving vitamin A nutrition through continuing to gift vitamin A capsules, creating dietary diversification through homestead gardens and husbandry to provide vitamin A rich foods, directing initiatives to fortify commonly used food such as cooking oil with vitamin A, and promoting the consumption and production of orange-fleshed sweet potatoes that have been bred with higher levels of beta carotene (a precursor to vitamin A) (Hki.org, 2011).

Farm Focus

Seventy-five percent of the world's poor live in rural areas and most are involved in agriculture. According to the WB (2012), agriculture remains fundamental to economic growth, poverty alleviation, and environmental sustainability. Rural industrialization is very limited so smallholder agriculture continues to be the source of growth while improving the lives of the rural (Berdegué and Fuentealba, 2011). To meet the challenge of improving incomes in rural areas, a transformation is needed from the low-input, low-productivity, semi-subsistent system that characterizes the majority of rural farming within the developing world (Govereh et al., 1999). The transformation is normally pursued through integration of cash cropping.

Cash cropping

A cash crop is one that is produced for sale. From the perspective of the small-scale farmer, the cash crop can be food or non-food use because its purpose is to generate revenue rather than to be consumed by the family. A subset of cash crops is export crops which are particular cash crops that are ultimately exported from the country. Political interventions promoting particular crops are typically focused on export agreements while micro level aid looks at supporting small-scale agriculture.

When reviewing the efforts of NGO's, the focus on cash cropping is to assist farmers in creating a crop for local markets. It deals with everything from teaching individuals with vacant land how to efficiently prepare a crop large enough to sell to helping change a farmer's crop selection so that the crop generates more income than what has been grown by the farmer in the past.

The most common commercialization in rural small-scale agriculture is the production of marketable surplus foodstuffs over what is needed for own consumption (Gebre-ab, 2006). This is because staple food crops have traditionally been produced under the subsistence system so it is believed that the smallholders have adequate knowledge and experience in these commodities (Jaleta et al., 2009). Interventions at the farm level are aimed at introducing new yield-enhancing technologies for subsistence crops to generate a surplus to be sold at market. This is seen as increasing household income at a lower risk while still improving the level of food security for poor farm families (Fafchamps, 1992). Small-scale farmers are typically risk adverse so different modes of production targeting high-value non-traditional commodities that could help farm households generate more income per unit of resources used are not commonly pursued because of the higher production and market risk that usually accompanies these strategies (Jayne, 1994).

The yield-enhancing technology most commonly used for cash crops is the application of fertilizers (Duflo et al., 2006; Banful, 2011). When the land area permits, development strategies may use mechanization to boost production levels allowing farmers to work larger amounts of land within planting and harvesting time periods (Singh, 2006). On a limited scale, crop interventions will implement hybrid seed programs. These programs are very minimal as a historical practice for subsistence farmers is to save seed for the following crop which becomes impossible with the majority of genetically modified seed varieties (Goldman, 2001).

Storage

When harvest comes, small-scale farmers typically sell their crop without storing it often due to their lack of storage facilities. In the absence of government price supports such as exist in the United States, most small-scale farmers sell their crops at harvest but often at a price that is lower than the seasonal average, all other things being equal. This problem (plunging prices at harvest) could possibly be reduced if farmers could wait past the end of harvest and sell (store the crop) when the price started to climb as supplies began to dwindle. In addition to cash crop storage for sale later, a need may be present for the household to hold inventories of staple foods they have raised (store) for later consumption. For these reasons, interventions have been devised to train small-scale farmers in improved handling and storage hygiene, using hermetically sealed bags, and construction of bulk storage devices such as silos (FAO, 1994; Baoua et al., 2012; Murdoch, 2012). In effect, better storage directly equates to greater food security.

Savings and warehousing can help farmers improve their bargaining power and provide greater returns to help lift them out of poverty. Providing a means for storing crops not only benefits the farmer through potentially increased revenue, it also helps minimize loss of crop and the aggravation resulting from the loss of the inputs invested in growing the crop such as irrigation water, human labor, and expensive fertilizer.

Creating ways for small-scale farmers to save staple foods efficiently minimizes their reliance on local markets for basic food items when producing foods for the farm family's own consumption may be less expensive than purchasing the food in local markets. In addition, storage may allow rural households to create stocks of food as a contingency against supply disruptions in food products sold at local markets.

Infrastructure

Once a surplus of crop is accumulated, the next challenge, in the case of a cash crop, is to get it to market. At the macro level this means that intervention designed to facilitate marketing may come by way of creating, improving, and/or expanding market infrastructure. Infrastructure is a key to farmers' bargaining power (Bond et al., 2012). Limited infrastructure brings condition where intermediaries dictate the price in the village, simply because they know farmers cannot afford to sell elsewhere (Joshi et al., 2007).

Current investments in infrastructure in the rural developing world now are appearing not to be under the umbrella of aid, but under the influence of agricultural outsourcing. The majority of the world's remaining cultivatable land lies in developing countries (Cotula et al., 2009). Current studies show that about 95 percent of Asia's croplands have been utilized which is forcing countries such as China to look elsewhere to feed their growing population. (Faostat.fao.org, 2012). The cheap and abundant farmlands in developing nations, particularly in Africa, drive capital rich nations to consider outsourcing their food production to these locations (Cotula et al., 2009). As of 2011, over 20 Chinese companies had been in negotiation with African and Latin American countries to invest in agriculture, food, forestry, fishery and biofuels activities (Afripol.org, 2010; Cobo et al., 2011; Saturnino et al., 2011). Africa and Latin America are where foreign investors are already creating access to arable land (Kye-Woo et al., 2012).

Currently China is at the forefront of the developed or semi-developed countries in developing infrastructure in the developing world; financing some of the largest infrastructure projects in the developing world. In eastern Africa, the Chinese are building a massive highway that is 16 lanes wide in some places that will help connect Ethiopia and Kenya (Langfit, 2011). In northern Africa, China and Japan are working together to build a 745-mile east-west highway across Algeria which will connect the country with Tunisia and Morocco (Newsmax.com, 2011). In Columbia, China is looking to build a 136-mile railway to compete with the Panama Canal and connect the Caribbean with the Pacific Ocean (Time.com, 2012).

Financial

Access to financial services for rural farmers is necessary as a means to increase their productivity including purchasing better inputs such as fertilizer and investing in better production and marketing methods. There is a huge need for financial tools to ensure the day- to-day operation of farms and to assist in their development (Mahajan and Vasumathi, 2010). This huge demand is faced with the very limited supply of credit in rural areas of the developing world, so few rural areas in the developing world benefit from access to credit facilities (Gine and Yang, 2009). Traditional and formal sources of capital funds are typically geared to be offered to large-scale rather than small-scale farmers so new financial tools have been designed to facilitate growth related to small-scale farming in the developing world.

Microfinance

Microfinance has often been described as a powerful tool in fighting poverty, specifically in very impoverished areas. Those who support microfinance efforts often refer to micro-credit programs as development initiatives that empower people to help themselves. Others highlight the “pay-for-itself” benefits of microfinance. In its infancy, microfinance issued the promise that it could provide a way to lift millions out of poverty with programs that would pay for themselves. Now that the novelty of microfinance has faded, microfinance has come under increasing scrutiny as aid organizations, development practitioners, and development partners continue to create microfinance interventions. Critics argue that the promised benefits of microfinance programs are not what they seem and that this financial vehicle rather causes harm to those it is was created to help (Bauchet et al., 2011).

The microfinance model is designed to provide poor people with access to capital which is supposed to increase investment in the short and long term by increasing cash flow in impoverished areas. Theoretically, the additional cash flow in these areas would lead to the acquisition of production assets, improve health and nutrition, and increase the level of education for household members (Pitt et al., 2006). Investments would then improve the households’ capabilities to respond to shocks and enhance their scope for putting in place preventative measures which would eventually assist them in lifting themselves out of poverty and reduce the risk of returning to it.

The evidence of the impact of microfinance reviewed for this project has revealed a much more complex picture exposing positive and negative impacts which suggests that there are some components of microfinance which must be addressed if microfinance is to serve the poor.

Beneficial Impacts of Microfinance

There is a large literature which finds beneficial socio-economic impacts as the result of microfinance. The recurring final effects reported in the literature are indicated as being income stability and growth, reduced income inequality, reduced vulnerability, employment, nutrition and health improvements, school attendance, strengthened social networks, and women's empowerment (Barnes, 1996; Schuler et al., 1997; UNICEF 1997; Barnes and Keogh, 1999; Wright, 2000; Khandker, 2001; Afrane, 2002; Beck et al., 2004; Hietalahti and Linden, 2006; Hossain and Knight, 2008; Coppock et al., 2011). One study specifically highlights that female micro-credit clients are more likely to invest in their children's nutrition and health expenses than those that do not participate in microfinance (Doocy et al., 2005).

Negative Impacts of Microfinance

It is equally easy to find studies alluding to potential negative impacts associated with microfinancing. The claimed unfavorable consequences resulting from microfinancing indicted in the literature included effects such as the exploitation of women, increased income inequality, creating dependencies, increased workloads, high interest rates, unchanged poverty levels, and creating barriers to sustainable local economic and social development (Adams and Von Pischke, 1992; Goetz and Sen Gupta, 1996; Rogaly, 1996; Buckley, 1997; Kabeer, 1998; Copestake et al., 2002; Bateman and Chang, 2009). A potential negative impact of microfinance interventions related to education was reported in Shimamura and Lastarria-Cornhiel's assessment (2010) of micro-credit initiatives in rural Malawi. The study was to evaluate the impact of agriculture credit on children's school attendance and found a correlation with the increased of time required in the fields by the adults and the decrease of female children's attendance at school as a result of the parents being involved in microfinance activities (2010). This was further supported by Barnes who reported that extended periods of borrowing reduce children's school enrollment (Barnes et al., 2001).

Mixed Evidence about Microfinance

Not all studies on microfinance are conclusive. For example, some evaluations show benefits for the poor but not for the poorest of the poor (Hulme and Mosley, 1996; Mosley and Hulme, 1998; Murdoch, 1998; Copestake et al., 2001). One particular study found that microfinance was effective in helping the poor to better manage the money they have (Rutherford 1996) but did not sufficiently enough to increase income (Husain et al., 2010). Karnani (2007) argues that money spent on microfinance interventions could be better used for other interventions, like supporting large, labor-intensive industries for job creation.

There is also literature arguing that a single intervention (such as microfinance) is less effective as an anti-poverty resource than simultaneous efforts combining microfinance, health, and education (Lipton, 1996). Another study of micro-credit in Ghana found initial mixed results for microfinance programs at the household and business levels in four districts. However, the longer the clients participated in the program, the more negligible the impact became in all four districts, compared to control groups (Nanor, 2008). This suggests that past examinations of microfinance program may have been carried out prematurely and may not provide accurate results to fully understand the long-term effects of these programs. This creates the argument that the success and failures of other interventions may have been greatly influenced by the timeframe in which results were collected.

In summary, the definition of “development” used influences how microfinance interventions are assessed in terms of success or failure. If the ultimate aim of microfinance is expanded beyond just increasing household or business income, microfinance interventions are generally judged to be more successful than if income is the only indicator of success for the program. Other indicators such as positive outcomes related to health and education tend to support the finding that microfinancing programs are successful (Roodman, 2012). Detailed analyses of income and expenditure at the household level appear to provide a more accurate indication of how microfinance interventions impact actual recipients and their family rather than analyses examining only the income generated by the business endeavors (e.g., expenditures on education, health care, and better food). However, focusing on non-wealth outcomes, such as health and education, without assessing financial indicators or considering both short- and long-term outcomes would also potentially provide misleading information. As indicated in the literature, families could increase their education and health expenses in the short term as a result of microfinancing programs, but fail to realize significant sustainable financial improvements for their households. Research focusing solely on non-financial outcomes might show an increase in education expenditure, without recognizing that there has been a reduction in overall income. Therefore, a careful analysis of all links between microfinance interventions and their connections to wealth and non-wealth outcomes is necessary to avoid distorted evaluations of microfinance interventions.

Savings and Investment by the Rural Poor

The poor save all the time. Savings are often the only way the poor can manage to pay for 1) a major life event such as a marriage or funeral, 2) survive a natural disaster, or 3) take advantage of a business opportunity. The poor rarely have access to voluntary deposit services offered by formal or semi-formal institutions. Instead, they are obliged to save informally.

The poor will convert their cash into livestock purchases, hide cash at home, employ their neighbors to collect it, or participate in rotating savings and credit associations. These informal savings devices can be categorized as being high risk, illiquid, and indivisible (Rim and Rouse, 2002). A cow, for example, can die of disease or must be sold as a whole to obtain cash (are lumpy in terms of economics). The opportunity does not exist for the farmer to sell just the rear quarters to pay for his child's schooling. The entire investment has to be converted to cash when a need arises. Additionally, the transaction incurs time and financial costs. Credit often serves the same purposes as savings for the poor even though it poses more risk and is typically more expensive. When electing to save, the poor are often willing to pay to do so (Banerjee and Duflo, 2006). Savings are arguably more important than credit in helping the poor to raise incomes and reduce risk. It can be argued, however, that the income impact may take longer to realize with savings (Cgap.org, 2006).

Insurance

The investment decisions of small-scale farmers in developing countries are conditioned by their financial environment. Borrowing constraints in the market and scarce insurance can reduce investment in activities with high expected profits. Increased insurance is associated with riskier production choices in agriculture (Karlan et al., 2012). Intervention programs have encouraged the use of inputs such as hybrid seeds and fertilizers to boost cash crop yields with their supporting evidence of high expected returns but continually coordinators are faced with opposition from subsistence farmers not wanting to diverge. The social gains from solving the risk problem could be substantial. If risk discourages the investment and the marginal return on investment is high, the returns to removing risk could be high (Dercon and Christiaensen,2011; Carter and Barrett, 2012).

When provided with insurance against the major risk they face, farmers are able to find resources to increase expenditure on their farms (Cai et al., 2010). When farmers have more capital, access to it, or available insurance, their production decisions are not as likely to reflect the bias of eating preference (Karlan et al., 2012). The opposite holds true when markets lack insurance and access to capital, the separation of the decisions of production and consumption does not exist. Interventions that communicate benefits from increased expenditure on fertilizer, land preparation by way of mechanization, and hired labor would do well to couple the program with a product such as insurance to lower vulnerability to shock thus increase adoption rate (Karlan et al., 2012). Subsistence farmers need access to insurance to take risks when they are so close to the poverty line.

Importance of Trans-Disciplinary Integration

The microfinance literature points out succinctly that a broad approach is called for when analyzing the impact of different possible interventions for the rural poor. This includes not only short-term impacts on income, but also household decisions to invest in education and health care. The literature also demonstrates the crucial role nutrition plays in the overall wellbeing of the rural poor in terms of their performance at work and school. Integrating household decisions and wellbeing into analyses is an important step to more fully understanding the complex interactions between economics, nutrition, and agronomy that determine whether or not any particular intervention can have both short-term and long-term beneficial results. Obviously, other factors such as culture, sociology, infrastructure, and disabilities affect the wellbeing of households. However, the focus of this study is on these components (economics, nutrition, and agronomy) as an initial step at integrating some of the general features of a household contributing to the sustainability of various potential interventions.

Understanding the impact of different interventions on several different dimensions of poor rural households provides a broader perspective of tradeoffs existing in the household in terms of how well-intended interventions may lack sustainability if they are not able to achieve objectives that result in better outcomes for the household that are independently integrated into the household's way of life. The model presented in this study consists of a mathematical linear program (LP) which incorporates the nutritional, economic, and agronomic characteristics of a typical agricultural household in northern Ecuador. The LP allows for the observation of how these dimensions (economics, nutrition, and agronomy) affect decisions made by the household and how some targeted interventions may or may not achieve the best outcomes in these three areas. It is anticipated that tradeoffs exist when considering different interventions and the LP sharpens and contrasts competition and complementarity between and among different goals that may be pursued with different interventions.

Successful interventions must achieve not only short-term but also the long-term positive outcomes for the household if they are to be fully integrated into the household way of life. In terms of economics, this would mean achieving goals such as permanent increases in average income and reduction of economic risks. For nutrition, it might mean assuring that children have enough nourishment to avoid long-term health problems and to be able to do well in school. For agronomy, it may mean being able to achieve better yields or better crop rotations. Taken separately, each of these goals would result in a positive outcome for the family. However, the goals may in fact be in conflict with each other. For example, changing crop rotations could result in more variety and availability of nutritious foods for the farm family but could result in a substantial loss in cash income. Consequently, interventions should not be considered in isolation but should also account for potential impact of other aspects of the farm family's life.

Many well-intended interventions focus solely on one aspect of need for the rural poor, such as nutrition. The thesis of this study is that combining several decisions faced by the farm family into a single, integrated model will provide additional insights regarding how different aspects of the farm family's lives interact. The result should be an increased understanding of how interventions may be designed to take into account more aspects relating to these households than just one.

CHAPTER 3

METHODOLOGY

A major underlying question and potential problem faced by sustainable agriculture and development efforts has been how to address the need for increased food production to coincide with increases in population while maintaining and preserving the earth's resources and environment (Economist, 2011). This is difficult given an expected global population of over nine billion by 2050 with approximately 80 percent of the surge in population expected to occur within developing countries (UN, 2012). NGOs and GOs are providing aid and implementing other interventions while looking toward options for improving agricultural production and welfare of some of the world's poorest farmers, the small-scale farmer. But, one of the easiest ways to accomplish this is with technologies such as fertilizer and chemicals that could harm the environment.

In 2011, over $130 billion was spent worldwide by mostly developed countries on development assistance and aid with over $41 billion going to the low-income countries (World Bank, 2010a). Recent estimates say that there are about 40,000 NGOs in the world in addition to other community-based organizations which number in the hundreds of thousands. Consequently, huge amounts of effort and resources are being expended in various good causes, including attempting to raise the world's poor out of poverty. Obviously, the problem of rural poverty is large, complex, and persistent. Many alternative goals and approaches to reducing rural poverty are being pursued by GOs and NGOs and certainly the majorities of these various efforts accomplish many good things and help people to have better lives.

This study recognizes that planning interventions to help the rural poor should take into account the interconnectedness of the financial, agronomic, and nutritional decisions of the rural poor who are often small-scale farmers. The approach taken is to develop an initial integrated model capable of measuring the impact of potential interventions on whole-farm decisions by small-scale farmers. The purpose of this model is to provide some initial illustrations of how those attempting to provide assistance to small-scale farmers might consider the impacts of these interventions on several facets of the farm family and their operation. The model proposed in this study provides an addition instrument which can be used to evaluate proposed and current economic, nutritional and agronomy-based programs (interventions) for their potential viability.

Economics is an important consideration in programs designed to help small-scale farmers and their families because if basic economic rules are violated, say that a proposed intervention does not improve overall economic viability for the small-scale farm, then it is highly likely that the intervention will not be sustainable and will cease to function (be used by the farm family) once funding ceases. The sustainability of interventions is, of course a primary concern for the assistance/aid community. Many programs in the past have enjoyed initial success and participation by small-scale farmers and other members of the rural poor, only to essentially disappear when funding was no longer made available to support the efforts of these programs.

Unsustainability (interventions which are unable to sustain themselves) may happen due to changes in focus by the government entities specifying the target of dollars going to aid. It also occurs when interventions depend on the grace of third-party donors and those donors move on to other projects or stop funding the current NGO. It may even be the original design of the intervention to end because it is implemented as a temporary trial with a planned expiration date. Often aid programs are rightly criticized for creating a dependence, a paternal aspect, on external participation so when the intervention ceases for whatever reason, the effort related to that intervention in the local area crumbles (FAO, 2006).

Nothing is free, but goods and services may be provided at no cost to the recipient of the goods and services provided by interventions. There is always an opportunity cost which is the next highest-valued alternative use of that resource. For the developing world, the idea of opportunity cost might be manifested in the time invested taking care of a new crop that could have been used instead to work at an unskilled job in a city. Although the intervention may be well-intended, those who implement the intervention may fail to assess the opportunity cost that the program creates. It is arguable that an intervention that makes a gift of inputs, such as vegetable seed, to small-scale farm families helps them to create a family garden which can lead to improved nutrition of the family. However, the intervention may have overlooked that the time spent caring for the garden could have produced income that could have purchased more food than was produced in the garden by working off the farm and then purchasing the same food in the market.

This thesis is an initial attempt to bring together agronomic, nutritional, and economic aspects to examine how different interventions in small-scale agriculture interact with these aspects of the farm. This is accomplished by using a LP model designed to maximize the income of a small-scale farm family in northern Ecuador while requiring that minimum nutritional requirements for a small-scale agricultural family be met.

The value of this economic analysis depends on the accuracy of the agronomic information included in the model such as expected production and costs. Costs and returns for a wide range of potential crops and livestock enterprises that could be produced on the farm were developed through information collected during a field survey focused in Cochas, Ecuador during August 2012. This information is synthesized and presented in enterprise budgets.

The Study Area

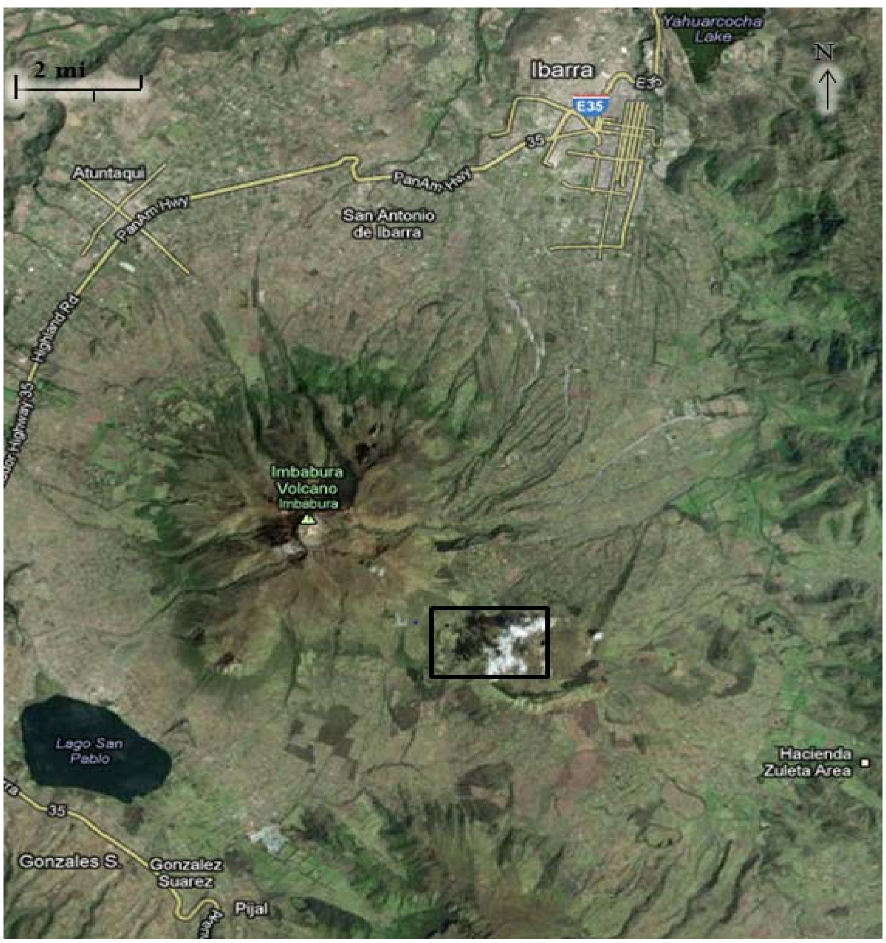

Figure 6. Map of General Survey Area of Cochas, Ecuador
Source: Google Maps

The community of Cochas La Merced is located within the province of Imbabura Ecuador near the Peruvian border. It sits on the Andes mountain range at about 2,800 meters above sea level. It takes approximately three hours to drive to the capital of Ecuador, Quito, and about one hour to drive to the local city of Ibarra.

The current community was a part of the Fraile plantation. When the last Fraile family member passed away, the land was given to the workers and their families. The land was divided into sections called "huasipungos" which is a Quichua word for a small portion of land for personal use. The divisions of land divided in this manner average between 1-2 hectares. The land is controlled by force meaning that few families are registered owners (have actual deeds) of the property on which they work. No written documents or descriptive coordinates that perfects a family's claim to land exist. It is possible to receive "escritura" (proven ownership) but the cost and know-how to do so are major inhibitors to these families doing so.

This community became the study area for this research. The study area was selected based on existing contacts with people and organizations operating programs in this part of Ecuador. Key contacts included the Institute for Self-Reliant Agriculture (SRA) and Capital Seed. The Ezra Taft Benson Institute has had programs in Ecuador for a number of years. SRA has close connections to the Benson Institute and has been operating programs as follow-ons to Benson Institute activities in this part of Ecuador. The Managing Director and Partner of Capital Seed, Mr. Justin Perry, was instrumental in setting up contacts for information and surveys in the study area. These connections and the fact that a number of different NGOs have operated in this part of Ecuador for a long time made this location a good choice in terms of the ability to gather the necessary agronomic, economic, and nutritional information that was required to complete the study.

Homes in the study area are built from bricks made with local clay and are sun dried. Floors are dirt, and walls are without windows. Roofs are fastened from straw, branches, and corn stalks. The local people wash their clothes by hand outside, and have minimal power requirements. Some of the people have a small gas cooktop. As of August 2012, the community census showed that the community had 196 homesteads and that all of them have water service. The potable water source is a natural reservoir located higher in the Andes on the side of an extinct volcano adjacent to the community. This reservoir is replenished by rain and snowfall each year.

Families that were contacted to provide information for this study and responded to questions in a survey that will be described later. The families participating in the survey ranged in size from single individuals to families of 12 or more. Some families living in the community may be even larger due to multi-generations living on the same sector of land. Average family size considered for this study was six and was composed of three children, both parents, and a grandparent. The household fathers in the area typically work in the town of Ibarra traveling each day to and from work by bus from home. Often though, fathers and older sons work for extended periods of time in Quito (performing manual labor) and returning home every eight to 22 days to help with harvest or to bring their earned money home.

Family farms in the study area have historically focused on producing field crops for cash market sale and daily consumption. The typical farmer engages in harvesting potatoes, corn, wheat, quinoa, and barley. The daily diets of the farm family have consisted primarily of these same food stuffs with sporadic consumption of vegetables purchased at local markets. But, vegetables are not considered staple parts of the average diet in the study area. SRA has recently become involved in the community in facilitating small-scale farmers in the incorporation of family gardens into their farm plan.

This community, like many rural small-scale and poor areas of the world, has a nonmarket orientation being they are subsistence farmers. They face abundant limitations in learning new production techniques, acquiring and use of technology, and do not depend on the local market to supply their food needs.

Process of Gathering Data for the Study

Primary data were collected through a survey in the study area during the month of August, 2012. The survey[4] was created with the goal of gathering the specific data needed to create enterprise budgets for different crops and also to create the social backdrop needed to better understand accepted agricultural practices as well as family characteristics.

The survey included sections designed to collect information needed to express the typical family through farm design and practices, and capture the economic situation that these families lived in (sample survey in Appendix F). All interviews were conducted in Spanish. An initial pilot survey was developed and administered to six families. This first survey was designed to test my proficiency in Spanish and to confirm the question formation. Spanish is not the only language spoken in this rural community.

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[4] The survey procedures received the necessary approvals from the Internal Review Board at Utah State University.

I was blessed with having a local guide to accompany me to facilitate the translation into Quichua should the need arise.

Within the first few surveys, it became evident that classical Spanish terms would not be appropriate in all questions. An example was the questions in the survey referring to fertilizer. In classic Spanish, the translation is “fertilizante” but the local term used is “abono.” Not only did this term and several others need to be changed, the actual formation of the questions had to be updated to mirror the sentence structure used in local conversation. Corrections were made based on what was learned in the initial survey and a final review practice survey was conducted with the local guide to verify the efficiency of the survey in collecting the data needed. The final draft of the survey was conducted with 20 families. Under the direction of the community president, Luis Alberto Anrrango Lechón, and treasurer, Maria Fabiola Churuchumbi Sandoval (also my town guide), 20 families were selected that she considered would reflect the over-all average family and farming practices within the community.

Each of the surveys was completed by the researcher to ensure integrity of answers and to clarify any misconceptions about what the questions we were attempting to ask. The surveys were carried out over six days. I would meet the available family members at their home at a designated time, with the assistance of the community guide. Most frequently we would be sitting underneath a shade tree or overhang of one of the houses to escape the scorching heat, while being in view of the crops area to facilitate the answering questions. Each survey averaged one hour to complete.

On arrival at the home, time typically needed to be spent earning the family’s trust. This culture requires relationships first before details of a private nature about the family and the farm are willing to be shared. The culture requires that the researcher and the family spend time getting to know each other before any information will be shared by the family. Due to the personal and sensitive information that the survey questions imposed, on the average, I spent an additional hour to an hour and a half creating the confidence needed to proceed with the interview. This additional time was not entirely focused at the beginning of each survey, but the need manifested itself within each survey when it was evident that time was needed away from the direct questions so that we could simply converse with the participants. Eventually the conversation would lead back to the focus of formulated survey questions.

After arrival and once the transition from small talk to the survey questions had occurred, the first portions of questionnaire were asked in fairly quick fashion. The conversation would then soon morph into a more informal conversation with the sharing of personal stories on the part of both parties with the survey questions being imbedded into the conversation. I believe this method allowed the interviewees to feel more relaxed as did I. I base this on the contrast between the frigid feelings which existed while administering the practice surveys during the previous days compared to the warm feelings which existed when a more informal conversation was pursued in the course of the survey with the respondents.

In addition to investing the six days in survey data collection, I participated in local events which supplied me with many supporting details. Within the events such as a class given on how to use a grain grinder, a town hall meeting, and a local farmer market; I was able to gain an increased relationship of trust within the local community.

I believe this contributed to the excellent and very specific information the last six families shared with me during the final round of surveys.

Besides the group events, I was invited multiple times to family meals and invested six hours rolling bread dough in preparation for the harvest festival. The discussions that occurred over the meal table and around campfires allowed me to better understand the dynamics of the relationships within this rural small-scale agricultural community. It was within these cherished opportunities that the culture became more evident to me by way of individuals expressing to me the trials that they face on a personal or family level. These intimate conversations partly influenced the selection of certain intervention studies that were reviewed in the literature section of this thesis. Knowing what the local people were experiencing and what outsiders had tried to do for them in the past helped me better comprehend what might or might not be an effective and sustainable intervention for the poor, rural farmers in this and other similar communities. This equipped me with the knowledge of possible available solutions that are specific to the rural poor throughout the world.

The surveys were successful in collecting the data needed to describe the typical agronomic, family, and economic situation used to develop the enterprise budgets and supporting tables. In addition to the surveys that were conducted, I was able to have conversations with family members from the majority of the households in Cochas during other events (there are a total of 198 households in Cochas). Pictures and videos were also recorded to facilitate recall of families and conversations. The locations of these interviews were also marked by GPS coordinates and recorded on the family surveys to facilitate information recall by providing me with photos of each area surveyed and to eliminate confusion between plots.

Enterprise Budgets

Enterprise Budgets estimate the costs and returns for an activity (enterprise) such as raising livestock, producing grain, or growing vegetables for a given production period (e.g., one year). Thus, enterprise budgets are frequently titled "estimated costs and returns." Decision makers can use enterprise budgets to evaluate options before committing resources to carrying out a particular activity. Enterprise budgets can help determine breakeven yields or prices and facilitate the calculation of potential returns on an investment. This level of itemization will ideally provide support in identifying profit and cost centers within the business. Enterprise budgets also provide critical input for whole-farm planning; including the potential income for a particular farm, the size of farm needed to achieve a given potential return, and anticipated cash flows during the year.

Enterprise budgets present information on the projected returns and costs associated with a particular crop or livestock enterprise. The information in an enterprise budget is presented in different sections (see Table 1 for an example of an enterprise budget used in this study). The first section of an enterprise budget reports anticipated revenue for the enterprise, the second section anticipated out-of-pocket (variable) costs, the third section non-cash costs such as unpaid family labor and depreciation on equipment and buildings. The final section of an enterprise budget describes the anticipated returns above costs that are projected for the enterprise.

Table 1. Estimated Costs & Returns for One Hectare of Quinoa in Cochas, Ecuador

		# / Hectare	Life (Yrs.)	Unit	Quantity	Price	Amount	
Revenue								
Quinoa[a]				Kg	782	$0.88	$688.16	96.2%
Seed[b]				Kg	18	$1.50	$27.00	3.8%
Total Revenue							$715.16	100%
Operating Expenses								
Seed				Kg	18	$1.50	$27.00	3.8%
Tractor[c]				Hour	6	$20.00	$120.00	16.8%
Tools[d]								
	Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	1.1%
	Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	0.9%
	Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	0. 6%
	Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	1.1%
Oxen[e]				Hour	2.00	$2.50	$5.00	0.7%
	Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.1%
Interest[g]					$70.00	18%	$12.60	1.8%
Total Non-Labor Operating Expenses							$190.77	26.7%
Returns to Land, Labor & Management							$524.39	73.3%
Return Per Hour of Labor							$3.86	0.54%
Return Per Day of Labor							$30.85	4.31%
Labor								
	Land Prep/Planting[h]			Hours	16	$0.63	$10.00	1.4%
	Maintenance[i]			Hours	40	$0.63	$25.00	3.5%
	Harvest[j]			Hours	80	$0.63	$50.00	7%
Total Labor Expense							$85.00	11.9%
Returns to Land & Management							$439.39	61.4%

[a] Average 800 kg.
[b] Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team used to cover seed behind tractor.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[h] Two people for an entire day to prep and plant. Supervising tractor, creating rows, covering seed.
[i] Mostly weeding, average two hours per week.
[j] Will need five workers for two days to clear field in a day.
*Farm gate price.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Revenue

The revenue stream created by selling agricultural products produced by the enterprise is located in the "Revenue" section of an enterprise budget (see Table 1). Revenue involves calculating the value as the product of price and the amount of agricultural product that would be available to be sold.

Enterprise budgets were developed for this study for a wide range of field crops, vegetables, and livestock enterprises. This was done as a method to benchmark crops and livestock that could be produced small-scale farmers in the study area. The enterprise budgets also became the basis for the economic portion of the LP model which selected which agricultural enterprises the farm should pursue to achieve its objectives. Developing the enterprise budget required assuming some basic information about the farm. This information was developed through the surveys. For example, the land area considered for the farm was one hectare, a fairly typical land area for a farm in the study area.

Field crop (see Table 2) yields were collected from over 20 families and synthesized to create average yields expected for each of the given enterprises. The full list of enterprise budgets created from the surveys is found in table 2. The full enterprise budgets compose Appendix A. Each field crop enterprise contains a footnote stating the average field size that was measured with corresponding yields. Because garden-type crops, such as vegetables, are grown on small plots of land, costs and returns were developed for them on a per square meter basis. Costs and returns were then scaled up to the hectare level assuming a linear transformation on prices, i.e., costs and returns per hectare were 10,000 times what they were on a square meter.

Table 2. List of All Enterprise Budgets Created for Cochas, Ecuador

Field Crops	Garden Crops	Animals
Barley	Beet	Guinea Pig
Chocho	Broccoli	Heifer
Maize	Carrot	Poultry
Oat	Cauliflower	
Potato	Celery	
Quinoa	Chard	
Wheat	Chinese Turnip	
	Green Cabbage	
	Green Onion	
	Lettuce	
	Onion	
	Radish	
	Red Cabbage	
	Spinach	
	Tomato	
	Zucchini	

The garden crop varieties are a recent addition to this rural community so yield recalls based on areas planted was not feasible. To create the best estimate, two farmers on two occasions accompanied me to the open air market. Before hand, we set the estimate of land yield to be measured as a 33 centimeter square due to this being the smallest amount of land that they have planted of any of the varieties. In the market, we compiled baskets of estimated yields per 33 centimeter square which were measured using a digital scale. The supplied yields were based on what the farmers could recall as being brought into the home for consumption. This helped to facilitate an accounting for field waste.

In retrospect, the yield assessed from the surveys for the garden crop varieties were overstated and could not be used in creating the enterprise budgets. Under the direction of Dr. Dan Drost, professor of horticulture and extension vegetable specialist for Utah State University, a more realistic yield was calculated based on averages in the United States.[5] This assumed, of course, that yields in Ecuador would not exceed those in the United States. The data to construct the potential yield was derived from the National Agricultural Statistics Service datasets and case studies conducted by other universities (Molinar et al., 2005; Kolota et al., 2010; Smith et al., 2011; Ucdavis.edu, 2012; USDA, 2012). The seeding rate developed from the surveys also presented a potential inaccuracy in the enterprise budges so these rates were reduced to reflect the information associated with yields in the USDA and university published datasets that were used to develop the yields used in the enterprise budgets. Dr. Drost, who has extensive experience working on issues related to vegetable crops not only in the United States but also in this part of South America, confirmed the validity of the adjusted yields and seeding rates used in the enterprise budgets.

Besides revenue from harvest, the budgets also include a line for seed income (see Table 1). The field crops include seed planted that is typically saved from previous harvest. Although no cash or credit was extended to supply the seed, it is included in the revenue as all inputs have a market value even when produced on the farm. This is to reflect the opportunity cost as they would be sold or eaten if not used in production.

Operating Expenses

The sum of variable costs and fixed costs make up the total cost of producing any farm commodity. Variable costs are the costs of inputs used during one production period and are variable because the total dollar value of operating inputs is a function of the amount used and amount of the commodity produced. Labor was excluded from this

[5] Using U. S. yields likely overstated perspective yields for the garden crop varieties, but was more realistic that what was generated using the method described earlier.

section of the enterprise budget (see Table 1) and accounted for in the third section of the enterprise budget to facilitate a comparison across enterprises of what the various enterprises could “afford” to pay for labor (based on income above out-of-pocket costs). This provided an estimate of the opportunity cost of labor when used to produce the various crops or livestock. That is, crops and livestock enterprises with the largest returns above out-of-pocket costs offered the highest economic “opportunities” for labor (farm family or hired labor).

Tractors are used in field preparation and seeding for some of the larger field crops. The tractor is rented from a nearby hacienda and the rental rate for the tractor includes a trained driver. Tractors are only used when the family cannot supply an adequate number of labor hours for planting within the designated time of the planting calendar. A planting calendar is a yearly schedule that designates the opportune time for planting with expected harvesting dates to create the greatest yields. The planting of field crops in this area of Ecuador is highly correlated with rainfall since no large scale irrigation is used with minimal considerations due to cold weather and adjustments accounted for being positioned along the equator. A crop calendar comprised of average planting dates for this community can be found in Appendix B.

Fixed costs are prorated over the expected life of the asset, based on straight-line depreciation, typically over a period of years. Fixed costs are not affected by short-term decisions and are associated with the normal wear-and-tear on tools and other equipment that are itemized under “tools” (see Table 1). The tools listed on the enterprise budget represent the average number and type of tools used by the surveyed farmers along with their average useful life.[6] The fixed costs listed in the budges are for the hand tools used to produce both the field crops and garden crops. Garden crops incur additional fixed costs associated with enclosure that must be built to keep out pests, such as rabbits, and irrigation system. The enterprise budgets for vegetable crops reflect the design of the typical garden areas managed by farmers in the survey. The participants in the survey who had gardens were gifted the enclosure materials by an NGO operating in the local area. The enclosures around the gardens consisted of landscape fabric for walls and fallen trees as posts for anchors. This was to protect the garden against extreme winds and wild predators. Drip irrigation systems used in these gardens were also gifted as part of an intervention program of the NGO.

Interest expenses for the garden crops is calculated in the enterprise budgets on direct expenses such as the seed, water, and drip system repair per square meter of garden (see Table 1). Field crop interest is assessed on tractor fees for preparing and planting and is charged based on the amount of time between the land is prepared and the crop is harvested and ready for market. An interest rate of 18 percent per annum was available for borrowed capital in the local town and this is the rate that was used to calculate interest expenses in the enterprise budgets. This rate may be low though compared to other areas in the developing world where it is reported that interest rates may be as high as 18 percent per month, resulting in interest rates in the hundreds of percent per annum (source). Total non-labor operating expenses are added and then subtracted from total revenue to arrive at the amount that would be available to pay the other non-cash inputs used in production.

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[6] The metal component of each tool may last longer than indicated and replacement handles may be made from tree branches.

Return to Land, Labor, and Management

The return to land, labor, and management summarizes the residual amount of revenue left after subtracting operating expenses (see Table 1). Essentially, return to land, labor and management must pay for family labor and other family resources devoted to producing the crop or livestock enterprise. If only returns above operating costs are used as the basis for judging the profitability of a particular intervention, it must be recognized that this assumes that family labor would be provided at no cost. Again, a basic rule of economics is that nothing is free. Opportunity costs for labor may be very low, especially in isolated areas of the developing world. In such cases, it may be justifiable to consider that labor, especially family labor, requires only a very small return when calculating the returns to any particular intervention. However, if family members have other potential opportunities, say to work off of the farm, then the return to land, labor, and management become extremely important because this return must compete with the other opportunities available to the farm family. Proposed interventions must account for the opportunity cost of the family's labor when calculating the potential benefits to the family. Otherwise, returns for the intervention may be overstated resulting in the probable unsustainability of the intervention once the donor ceases to provide funding for the intervention.

Labor

The return per hour of labor is calculated by summing the hours of labor needed in the time frame (length of the production period such as a year or six months) required for the enterprise and divided the sum into the previous line of returns to land, labor, and management. The "return per day of labor" is calculated by multiplying the "return per hour of labor" by eight hours. The daily pay in the area for a "peon," day laborer, is $5.00. The average amount of the day that a worker is in the field is eight hours.

Paid workers will typically spend the entire day working the land with lunch and supper provided. An 8-hour work day at $5 equates to $0.625 per hour and this rate is used to calculate the expense for the different subareas of "labor" in the enterprise budgets (see Table 1). Wage rates off the farm tend to be higher than for on-farm work. However, caution should be exercised when comparing the wage for hired labor on the farm to the wage that could be earned off of the farm. On-farm productivity, and hence, the return on hired farm labor are dependent on how productive and profitable different crop or livestock enterprises are. Conversely, even though off-farm wage rates might be higher than on-farm wage rates, one must also subtract from the off-farm wage rate any costs associated with working off of the farm such as travel to and from work and the cost of meals away from home when at work. The labor expense for producing the enterprise at the $0.625 hourly rate is summed and presented by "total labor expense" in the enterprise budget (see Table 1).

Returns to Land and Management

In enterprise budgets when no land charge is included, returns should be interpreted as being returns to land and management. In the community of Cochas, land has no direct cost (see study area section). Positive returns above total operating costs indicate that the enterprise is self-supporting and generates enough revenue to cover all variable costs and all, or at least some portion, of fixed costs. If an enterprise can cover its costs, including opportunity costs, it creates a scenario where producing more of the profitable crop or livestock enterprise would result in higher returns for the farm family.

In other words, the enterprise could be scaled up and the farm family would make more profit after covering expenses. This would also reward the operator financially for managerial skills. However, if returns to an enterprise are negative, the enterprise is not generating enough revenue to cover costs and eliminating this enterprise will increase profits or minimize losses by decreasing losses in the overall operation.

Percentages

Each enterprise budget developed for this study includes a column on its far right illustrating the percentage of each line item compared to total revenue (see Table 1). For example, revenue streams percentages indicate what proportion each activity contributes to total revenue. For expenses, the percentage specifies what proportion amount of gross revenue is consumed (expended) on that component of costs to produce the enterprise.

Summary of Enterprise Budgets

The enterprise budgets presented in this study are designed to provide a framework for making projections about the short- and long-range sustainability of various interventions based on an economic analysis of agriculture production. The enterprise budgets will assist in understanding the costs and returns of different production activities, identifying potential sources of risk, and evaluating alternatives. Knowledge of the data used to create the estimated costs and returns will assist producers in making sound business decisions and we believe this is the first time formal estimates of costs and returns for these various enterprises have been completed for the study area. When producing vegetables on a small scale (or any other enterprise or scale for that matter), it is important to know costs. These enterprise budgets should be used as a benchmark for understanding the components of costs and returns for these enterprises in the study area. As such, they serve as the basis for the economic portion of the analysis using the integrated LP which will be described later in this chapter.

Crop Calendar

The selection of food to be grown and purchased depends heavily upon the availability of each of the food stuffs on the family farm. A crop calendar for this community was derived from responses to the survey as well as from conversations conducted during a community farmers market held at the community office (Appendix B). The community market provided a large amount of input regarding crop schedules with minimal time consumed compared to the time required to obtain such information through the surveys. I estimate that over 40 families contributed information about cropping dates to facilitate the creation of the calendar.

For the field crops, most families followed planting dates of close proximity with correlated harvest ranges but no such "typical" selection of planting dates existed for garden crops. The general consensus provided by the farm families was that any of the garden varieties could be planted at any time of the year. This coincided with what they had been instructed by a NGO. This seemed to be supported in practice in that different farmers had similar garden plots planted but the range of planting dates varied widely from farmer to farmer. The crop calendar in Appendix B provides multiple planting dates for many of the crops reflecting actual practice. This allows the model to select different periods to plant based on need and available land. The families did state though that there were better times of the year to plant certain garden and field varieties because the different crops required different amounts of water. However, temperatures were not stated as the limiting factor in determining when to plant garden crops. A separate table consisting of average time accruing between planting and harvest is included in Appendix B. A common practice of the surveyed families was to leave the crop in the field or garden longer than the calendar states because it provided an alternative method to store the food and reduce spoilage.

April is the month with the heaviest rainfall in the study area and June through September are the driest months. Because this area of Ecuador is considered tropical, one might assume that it receives rainfall throughout the year with some months being drier, but not completely dry. However, this area of Ecuador receives no rainfall typically during the dry months even though the national weather station located about 18 miles away claims it does (Inamhi.gob.ec, 2012). The residents were very proud of their volcanic soil and said they rely on it retaining water to grow potatoes and keep their maize (corn) alive in the dry months. The gardens were supported via drip irrigation system to provide adequate amounts and a consistent source of water.

Linear Programming

A mathematical technique that determines the best way to use available resources is linear programming. Essentially, LP optimizes an objective function that is subject to a number of constraints. For example, the objective function of a farm family might be to maximize income. However, the family is subject to numerous constraints such as the amount of land they have, the amount of family labor available, and access to resources such as fertilizer. The concept of LP is to solve this problem mathematically such that the constraints faced by the farm family are met or accounted for while at the same time using their resources (land, labor, and capital) in the best way to increase their income. For example, crops and/or livestock enterprises that are best suited to the land and labor endowment while offering the highest returns of the alternative enterprises that could be produced will be selected and reported by the LP. LP allows for interacting of the various constraints when arriving at the "optimal" solution. Consequently LP does a relatively good job of accounting for the complexities presented by the various constraints on resources but still can produce relatively straight-forward solutions to these complex problems.

While LP can provide analyses of the profitability of different agricultural strategies and enterprises based on a given set of economic constraints, it is also well suited for solving mathematical problems related to nutritional requirements and nutritional uptake. This is especially relevant for the nutritional issues faced by poor, rural families. Given available foods and food prices, LP can solve for the least cost combination of foods in a given time period to meet nutritional goals such as minimum calorie intake, minimum protein, intake, and other nutritional intake targets. In summary, LP can assess the possibility of satisfying nutritional intakes in a poor rural area, the price for the most nutritionally feasible diet, and can integrate nutritional requirements into whole-farm planning for profit while satisfying the nutritional needs of the farm family.

Darmon et al. (2002) made use of LP to find the manner and probability that rural preschool children in Malawi achieve a nutrient dense diet. As in Malawi, the diets of children in other poor countries are frequently deficient in key nutrients such as vitamin C, vitamin A, iron, zinc, calcium, and riboflavin (B6) (Riddoch et al., 1998; Bekaert et al., 2008; Fleige et al., 2010; Verkaik-Kloosterman et al., 2012). These deficiencies can be explained by either a shortage of micronutrient-dense foods which are foods with high concentrations of nutrients relative to energy (carbs and starches). Darmon et al. (2002)

found that although nutrition improves due to educating people on increased consumption of fruits and vegetables, nutritional inadequacy will persist due to availability of these foods. Depending on the source of deficiency, availability or selection, the possibilities have different programmatic implications. Availability suggests that the deficiency can only be improved by increasing the readiness of nutrient-rich foods, either through food fortification or agricultural programs that introduce new crop varieties. A deficiency due to poor menu selection suggests that nutrition education programs that focus on the best use of locally available foods should be given priority.

LP can be applied to identify a nutritionally adequate diet at the lowest cost. This approach is facilitated by the relationship of price and nutrient contents as they are linearly related to food weight. Conforti and D'Amicis (2000) utilized LP in studying the diet consumption structure and expenditure in Italy. The goal was to compare current diets and associated costs with nutritional prescriptions that follow recommended daily allowances. The findings claim that an adaption of a nutritionally adequate diet in the developed world is unlikely to increase food expenditure. For the developing world, Andre Briend (2003) of the Scientific and Technical Institute of Nutrition and Food advances the argument in using linear programming. He argues that linear programming can create a least cost diet and eliminate expert guessing and the trial and error approach.

Field crop production is a major component of the small-scale farm family economy. The large body of literature that now exists on the use of LP in crop selection and farm production analysis focuses on large-scale commercial farming and very little on small-scale farms in developing countries. The models are generic in providing suggestions to maximize profit given a set of inputs. In 2003, Adejobi et al. employed

LP in the savannah of Nigeria to reveal the optimal crop enterprise. They show that only a mix of cropping enterprises is feasible when a constraint of supplying food for consumption is applied in addition to maximizing profit. Generally, LPs suggest the best management practice would be monocropping. Monocropping is synonymous with modern agriculture and is widely implemented in the developing world (Bazaraa and Bouzaher, 1981). Its advocates claim the need for economies of scale while being the most efficient (Madeley, 2002).

Nutrient Requirements

The set of nutrient reference standards, dietary reference intakes (DRIs), for the United States and Canada were consulted to create nutritional constraints. These values are the recommendations from the United States National Academy of Science's Institute of Medicine (IOM). DRIs consist of Estimated Average Requirements (EAR), Adequate Intake (AI), Recommended Dietary Allowance (RDA), and Tolerable Upper Intake Level (UL). RDAs were chosen to form the constraints as they are sufficient to meet the nutrient requirements of nearly all healthy individuals in a group, 97-98 percent, thus presenting a low risk of inadequacy (Beaton, 2006). Where RDAs were not available, AIs were substituted which was the case for infants zero to 12 months. A summary of the recommended dietary allowances (RDAs) and adequate intakes (AIs) is found in Appendix D.

MyPlate

MyPlate is an illustration based way to approach satisfying nutritional requirements. It depicts the five food groups, fruits, vegetables, grains, protein foods, and dairy, that should constitute daily meals in a well-balanced and nutritious diet. This is the U. S. government's replacement for the Food Pyramid. It has been designed to help individuals consume a more balanced diet by providing a reference tool that is in a simpler format than the previous pyramid. MyPlate is also a more manageable concept to understand compared to the nutrient table of RDAs which requires measuring and remembering intakes in milligrams, grams, micrograms, and percentage numbers of daily intakes.

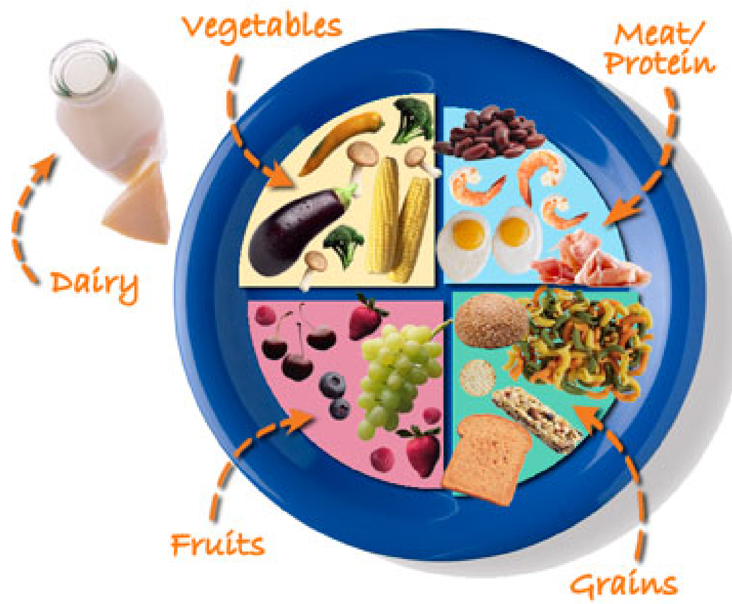

Figure 7. Example of MyPlate Illustration
Source: Healthyadvice.com

MyPlate is an "ideal" approach to nutrition and is geared primarily to people in the developed world who often face very different nutritional problems than people in the developing world. For example, people in the developed world tend to consume too much saturated fat which can lead to cardio-vascular disease. On the other hand, simply consuming enough calories each day to be able to function well and work hard may be one of the primary nutritional problems faced by persons in the developing world.

Consequently, MyPlate may or may not fit well with the nutritional realities faced by poor people in the study area. However, it is used as one point of reference in understanding some of the basic differences in nutritional issues between the developing and the developed world.

Genesis

The automated software service called Genesis was used to find estimated nutritional content for different food values used in the LP model. The software manages a database of over 50,000 food items with full nutrient values supplied by over 1700 reputable sources (Esha.com, 2012). Each food that was considered in the LP as a possible food source for the farm family in the study area, was selected from the USDA Standard Reference database and then had its nutritional content was calculated.   A nutrient summary of all foodstuffs is provided in Appendix C. In addition to supplying raw food nutritional data, the Genesis analyzes the nutrient content of food and calculates yields from moisture, fat, cooking, and processing gains and losses. One hundred gram portions (considered to be one portion of each food) were used to measure available nutrients that a food provides and that the model may select to satisfy nutritional constraints.

Parameters Used in the LP

Family Labor

The family's labor constraint established for the LP was developed off of the available the husband in the household would be able to work whether off- or on-farm. To match the planting calendar that was developed based on half-month cropping periods throughout the year (24 cropping periods total), family labor availability was calculated in the same fashion and the husband was assumed to have 100 hours in available work time available during each one-half-month period. This estimate is based on working a 40-hour week plus allowing an additional ten hours of work, beyond a normal 5-day week, that could be completed on the weekend. In surveying farm families in Cochas, questions covered the efficiency of work that is carried out by members of the family, other than the father, in terms of how long it took each other member of the family to complete a task in the same amount of time as the father. The averages reported by the surveys suggest that the mother, grandma, and daughter would be able to complete 60, 40, and 50 percent respectively, of the task that the father would accomplish in an hour. With these percentages, the mother was allowed 60 hours per week of work, the grandma 40 hours, and the daughter only 40 in an attempt to adjust for hours while the daughter is at school for nine months of the year and unavailable to work on the farm. The son was not included in available labor but is recognized that typical practice in this area was to allow younger children to help with weed removal, penning smaller animals, and collecting crops from the field but the overall contribution of son to total family labor is considered minimal.

Pantry Items

Certain food items were included (set by determination) in the diets of all families; pepper, salt, oil, brown sugar, and eggs. During initial runs of the model, these items would either not appear in the results as satisfying any nutritional requirements or would be included in an enormous amount due to the least-cost ration feature of the LP using large amounts to supply a particular micronutrient. To eliminate unrealistic results due to these issues, a set amount of each of these items (pepper, salt, oil, brown sugar, and eggs) were considered “pantry” items and were included in the model (see Table 3). Of these pantry items, only oil was allowed to provide nutritional benefit but only at the rate of 75 percent of quantity supplied to account for loss in frying compared to high absorption in baking.

Table 3. Pantry Items Purchased In All Scenarios Expressed In 100 Gram Increments For Each Month

	Minimum	Maximum
Pepper	0.08	n/a
Salt	0.417	n/a
Oil	9	9
Brown Sugar	20	20
Eggs	12	n/a

School Expenses

The average family in the surveyed population had at least one child attending school. The expenses a family incurs due to a child’s school participation vary widely in the study area. The education system in Ecuador provides no-cost school enrollment, but there is also a large supply of private schools within the same market. Although enrollment may be at no charge in public school, the family needs to purchase uniforms, books, meals, supplies, and transportation for the child to attend. For both public and private education, the expenses were estimated to be similar for related charges. The average estimated expenses for supplies, uniforms, lunch, breakfast, books, and transportation is found in Table 4. Meals are provided at some of the private institutions with no extra fee. Many schools within the Imbabura region participate in school lunch programs that are subsidized by the government. This isolated community had a local elementary school that serviced the elementary-aged children and was staffed frequently with traveling professors from developed countries. An education expense that reflects an average for a ten and six-year old was included in the LP at $795 total per calendar year (see Table 4).

Table 4. List of Average Individual School Expenses

	Average	Unit
School Supplies	$ 20.00	year
Uniforms	$ 75.00	year
Lunch	$ 2.50	month
Breakfast	$ 5.00	month
Books	$ 100.00	year
Bus Fair	$ 1.50	day

Expenses for Utilities

The average utility expense per household was $9.50 per month. This was comprised of $3.50 for bottled gas, $2.00 for electricity, and $4.00 for water. The twelve-month average total of $114.00 was used as the set utility expense in the LP.

Medical

Each family member suffers from some disease or infection on the average each year. An average charge for a visit to the doctor was $50.00 with emergency services being much higher. Many of the elementary schools have a nurse on site and the attending children are allowed to receive treatment free of charge at school. Junior high and high schools also had medical staff on site which provides treatment at a discount and with the average cost of a doctor visit being $15.00. Blood tests were a routine part of the typical treatment at doctor’s offices and average cost for a blood test was $20.00. Prescription services were sometimes provided at no charge but averaged about $25.00

per incident. A yearly average medical expense of $350.00 for the farm family was used in the LP model.

Creation of the LP

A basic explanation of the objective function of the LP is the following (not all detail included):

(1) Maximize

$$-\sum_i \sum_j A_{ij} B_i + \sum_j \sum_k C_{jk} D_k + \sum_j \sum_k G_{jk} F_k - \sum_m \$0.625 H_m + \sum_m \$0.96 I_m - \sum_n J_n K_n - UTILITIES - MEDICAL - SCHOOL$$

Subject to:

(2) $\sum_i A_{ij} L_{ir} M_i + \sum_k N_{kj} L_{kr} M_k + \sum_n (J_n L_{nr} M_n N_n)/12 \geq NUT_{jr} \;\; \forall\, j \text{ and } r$

(3) $\sum_k G_{km} \leq 10{,}000 \;\forall\, m$

(4) $J_n \leq 10 \;\forall\, n$

(5) $J_2 \leq 2$

(6) $\sum_k (G_{km} - N_{km}) \geq 0 \;\forall\, m$

where:

A_{ij} = the i^{th} food purchased during the j^{th} month

B_i = the per unit price paid for i^{th} purchased food

C_{jk} = the amount of k^{th} raised crop sold during the j^{th} month

D_k = the per unit price for the k^{th} crop

G_{jk} = the total amount of the k^{th} crop raised on the farm during the j^{th} month

F_k = the variable costs of production for the k^{th} crop (does not include a charge for family labor)

H_m = the number of hours of non-family labor hired during the m^{th} half-month period

I_m = the number of hours worked off the farm by the family's father during the m^{th} half-month period

J_n = the number of the n^{th} livestock type owned by the family

K_n = the variable costs of production for the n^{th} livestock type (does not include a charge for family labor)

UTILITIES = average annual utility charge for the family

MEDICAL = average medical expenses for the family

SCHOOL = average annual school expenses for the family

L_{ir}, L_{kr}, L_{nr} = the amount of the r_{th} nutrient in one kilogram of the i^{th}, k^{th}, and n^{th} purchased food, respectively

M_i, M_k, and M_n = the cooked yield in percentage for the i^{th} and k^{th} vegetable purchased or grown on the farm, respectively, and the n^{th} livestock product

N_n = the number of units of the livestock product produced by each n^{th} livestock type

NUT_{jr} = the minimum nutrient requirement of the r^{th} nutrient during the j^{th} month for the farm family of six

i = barley flour, barley hulled dry, beets, broccoli, carrots, cauliflower, celery, Chinese turnip, corn, green cabbage, green onion, oats, potato, quinoa, radish, red cabbage, spinach, tomato, wheat flour, wheat whole grain, white onion, zucchini, chocho, rice, oil, brown-sugar, cow milk chicken, pig, lamb, cuy, beef, eggs, pineapple, apple, peach, banana, salt, pepper, water, corn flour, chard

j = January, February, March, April, May, June, July, August, September, October, November, December

k = barley, beet, broccoli, carrot, cauliflower, celery, chard, Chines turnip, chocho, corn, green cabbage, green onion, lettuce, potato, quinoa, radish, red cabbage, spinach, tomato, wheat, white onion, zucchini, oats

m = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

n = guinea pig (cuy), heifer, poultry

r = calories, fat, cholesterol, sodium carbohydrates, fiber, sugar, protein, vitamin A, vitamin C, vitamin B12, vitamin B6, calcium, iron, riboflavin, niacin, thiamin, folate,

The objective function (equation (1)) indicates that the farm family's objective is to maximize its income (livelihood and standard of living). The family's income is determined by subtracting the costs of food purchased, wages paid to hired labor, and household expenses (utilities, medical, and school expenses). Additions to income include revenue from the sale of crops and off-farm income.

Constraints placed on the objective function include that the family's nutritional needs be met each month (equation (2)) either through food that is purchased or raised on the farm. Equation (3) places a limit of no more than one hectare of the farm being planted in crops during each one-half month period. Equation (4) indicates that no more than ten animals of each animal species considered could be produced on the farm while equation (5) limits the farm family to having no more than two cows. Equation (6) indicates that the amount of crops sold may not exceed the amount of crops raised on the farm during any given half-month period.

LP Model Scenarios

The LP can be used to illustrate many different possible outcomes for the farm family. This is done through adjusting the constraints of the model to meet specific targets or goals (Table 5). The targets selected for this study attempt to mimic possible economic and nutritional interventions which could be pursued in an attempt to assist the farm family to improve their lives. Each different goal or target is described below in a "scenario." The scenarios are the basis for the LP analysis (Table 6). The results for the different scenarios are contrasted and compared to provide a better understanding about how potential interventions interact across the nutritional and economic goals of the family. The end result is a more general understanding of how interventions need to consider outcomes across many facets of the family's life and not just a single possible outcome or narrow perspective.

All the scenarios assume that the land available to the farm family is one hectare (10,000 square meters). Family expenses for school, medical, and utilities are constants in all scenarios at a set price of $1159.00. Scenarios designed to satisfy basic nutrient requirements are based on selected RDAs while MyPlate scenarios are designed to satisfy

Table 5. General Linear Programming Model, Small-Scale Farm in Cochas, Equador

Constraints	Buy Food	Eat Crops	Sell Crops	Sell Veg	Store Crops	Grow Crops	Raise Livestock	Hire Labor	Work Off Farm	Family Expenses		RHS
	Activities											
OBJ	-		+	+		-	-	-	+	-		Maximize
Nutrition Min.	+	+					+				>=	Min. Nutrition Req.
Max Food	+	+					+				<=	Max. Weight of Food
Max Select Foods	+										<=	UL Select Foods
Min Food Req.	+						+				>=	Min. Food Req.
Land Use						+					<=	10,000 m^2
Sell Vegetables				+							<=	0
Max Livestock							+				<=	Max Livestock
Balance Crops		+	+	+	+/-	-					<=	0
Balance Labor						+	+	-	+		<=	Family Labor Supply

Table 6. List of Scenarios Run With Brief Description

Scenario 1	Satisfying RDA of Nutrients by allowing food purchases, allowing off-farm income, no hired labor
Scenario 2	Satisfying RDA of Nutrients by allowing food purchases, no off-farm income, no hired labor
Scenario3	Satisfying RDA of Nutrients without purchasing food, no off-farm income, no hired labor
Scenario 4	Satisfying RDA of Nutrients without purchasing foods, allowing off-farm income, no hired labor
Scenario 5	Satisfying RDA of Nutrients by allowing food purchases, allowing off-farm income, hired labor
Scenario 6	Satisfying MyPlate servings by allowing food purchases, allowing off-farm income, no hired labor
Scenario 7	Satisfying MyPlate servings by allowing food purchases, no off-farm income, no hired labor
Scenario 8	Satisfying MyPlate servings without allowing food purchases, allowing off-farm income, no hired labor
Scenario 9	Satisfying RDA of Nutrients by allowing food purchases, with off-farm income, no hired labor, no heifer
Scenario 10	Satisfying RDA of Nutrients by allowing food purchases, no off-farm income, no hired labor, no heifer
Scenario 11	Satisfying MyPlate servings by allowing food purchases with off-farm income, no hired labor, no heifer

the number of portions of the different food groups as specified in MyPlate. Some of the scenarios are designed to illustrate how farm choice change based on opportunity costs. This is modeled by comparing farm family choices when assuming or relaxing constraints of the amount of 1) family labor available and 2) the opportunities for off-farm employment (see Table 6 for list of scenarios).

Scenario 1

The base scenario for this model is set to fulfill the basic nutrition requirements of the family of six through food that is either produced on farm or purchased in market. The father is allowed to work off-farm (up to 100 hours during each half-month period) but also limits the family to not hiring labor. Field crops (e.g., potatoes and corn) may be sold but garden crop varieties are limited to be only for family consumption (cannot be sold). Products produced by animal enterprises (e.g., eggs, milk) are also allowed to be used only for family consumption (not sold) with the exception of the heifer’s calves which may be sold. This scenario illustrates a small-scale agricultural family in which the father has the opportunity to work off-farm and transfers the labor requirement to operate the farm mostly to remaining family members if the father works off of the farm. The base scenario will be referred to as scenario 1 (S1).

Scenario 2

The second scenario (S2) is designed to fulfill nutritional requirements of the family of six through food either produced on the farm or purchased at the market. Field crops may be sold but garden crop varieties are limited to family consumption. Products produced by animal enterprises are only used for family consumption with the exception of selling the heifer’s calves. No members of the family are allowed to work-off farm and the farm family is also assumed to not be able to hire non-family labor. This scenario reflects a farm family that depends on field crops to create a revenue source to pay off-farm expenses and the family is responsible in providing all labor required for production.

Scenario 3

The third scenario (S3) is designed to fulfill basic nutritional requirements for the family of six through food produced only on the farm. Field crops may be sold but garden crops varieties are limited to family consumption. Products from animal enterprises are consumed only by the family with the exception of selling the heifer's calves. No members of the family are allowed to work-off farm and they also cannot hire non-family labor. This forces the model to grow crops to satisfy family consumption while providing the opportunity to sell field crops to create revenue to pay for off-farm expenses. The farm is limited to the existing number of family work hours to satisfy production needs without hiring labor in an effort to be self-sufficient.

Scenario 4

The fourth scenario (S4) is designed to fulfill nutritional requirements for the family of six through food produced only on the farm. Field crops may be sold but garden crop varieties are limited to family consumption. Products from animal enterprises are only for family consumption with the exception of selling the heifer's calves. The father is allowed to work off-farm but non-family labor is not allowed to be hired. This scenario illustrates a family that is attempting to eliminate food purchases and be self-sufficient or a family that is located in an area that does not have a local market to purchase food. If satisfying nutritional requirements is impossible with on-farm food production, the model allows food purchases at a premium and allows the model to solve. This scenario will also provide a comparison of crop selections in S3 when the available family labor is reduced while producing a higher standard of living.

Scenario 5

The fifth scenario (S5) is designed to fulfill nutritional requirements of the family of six through food either produced on farm or purchased at the market. The father is allowed to work off-farm and the family is also allowed to hire non-family labor. Field crops may be sold but garden crop varieties are limited to family consumption. Products produced by animal enterprises are used only for family consumption with the exception of selling the heifer's calves. This scenario illustrates an entrepreneurial family where the father could work off-farm while the family employs replacement labor to satisfy production demand.

Scenario 6

The sixth scenario (S6) for this model is designed to fulfill MyPlate servings requirements for the family of six through food either produced on farm or purchased at the market. The father is allowed to work off-farm but non-farm labor is not allowed to be hired. Field crops may be sold but garden crop varieties are limited only to family consumption. Products produced by animal enterprises are used only for family consumption with the exception of selling the heifer's calves. This scenario illustrates a small-scale agricultural family in which the father has the opportunity to work off-farm and when he does the farm labor previously provided by the father is shifted to the remaining family members. This places a strain on on-farm production, but provides an alternative source of cash from the off-farm job taken by the father. It is a mirror of S1 except that the equation is satisfying servings of food instead of the specific RDAs.

Scenario 7

The seventh scenario (S7) is designed to fulfill MyPlate servings requirements for the family of six through food either produced on farm or purchased in market. Field crops may be sold but garden crop varieties are limited only to family consumption. Products produced by animal enterprises are used only for family consumption with the exception of selling the heifer's calves. No members of the family are allowed to work-off farm and the family cannot hire non-family labor either. This scenario is set to reflect a family that depends on field crops to create a revenue source to pay off-farm expenses. The family is solely responsible to provide all labor required for production. It is a mirror of S2 except that the equation is satisfying servings of food instead of the specific RDAs.

Scenario 8

The eighth scenario (S8) is designed to fulfill MyPlate servings requirements for the family of six through food produced on farm but limiting food purchased in the market by artificially inflating retail price by 90 times. This allows the family to purchase food at a premium if it is impossible to satisfy nutrient requirements with only family-grown food in a period. Field crops may be sold but garden crop varieties are limited only to family consumption. Products produced by animal enterprises are only for used for family consumption with the exception of selling the heifer's calves. No members of the family are allowed to work-off farm the family cannot hire non-family labor either. This forces the model to grow crops to satisfy family consumption while providing the opportunity to sell field crops to create revenue and pay for off-farm expenses. The farm family is limited to using only family work hours to satisfy production needs without hiring non-family labor. It is a mirror of S3 except that the equation is satisfying servings of food instead of the specific RDAs.

Scenario 9

The ninth scenario (S9) for this model is designed to fulfill nutritional requirements for the family of six through food either produced on farm or purchased at the market. The father is allowed to work off-farm but the family hires no non-family labor. Field crops may be sold but garden crop varieties are limited only to family consumption. Products produced from animal enterprises are used only for family consumption and this scenario eliminates the heifer from the farm animal set. This scenario illustrates a small-scale agricultural family in which the father has the opportunity to work off-farm and transfers the labor requirement to run the farm to remaining family members which strains on-farm production but provides an alternative source of cash from the father's off-farm job. This scenario illustrates a family that does not possess or have access to the capital required to purchase a lactating cow that births one calf a year. The family also does not have sufficient cash flow to purchase a calf and maintain her till producing age. This scenario mirrors S1 except that the heifer is not an animal that the family can choose to produce.

Scenario 10

The tenth scenario (S10) is designed to fulfill nutritional requirements for the family of six through food either produced on farm or purchased at the local market. Field crops may be sold but garden crop varieties are limited only to family consumption.

Products produced by animal enterprises are used only for family consumption and this scenario also eliminates the heifer from the farm animal set. No members of the family are allowed to work-off farm the family also cannot hire non-family labor. This scenario reflects a family that depends on field crops to create a revenue source to pay off-farm expenses and is responsible for providing all the labor required for production. This scenario illustrates a family that does not possess or have access to the capital required to purchase a lactating cow that births one calf a year, or have sufficient cash flow to purchase a calf and maintain her till producing age. This run mirrors S2 except that the heifer is not an animal that the family can choose to produce.

Scenario 11

The eleventh scenario (S11) for this model is designed to fulfill MyPlate servings requirements for the family of six through food either produced on farm or purchased in the local market. The father is allowed to work off-farm and but the family is unable to hire non-family labor. Field crops may be sold but garden crop varieties are limited only to family consumption. Products produced by animal enterprises are used only for family consumption and this scenario also eliminates the heifer from the farm animal set. This scenario illustrates a small-scale agricultural family in which the father has the opportunity to work off-farm and transfers the labor requirement to run the farm to remaining family members which strains on-farm production but provides an alternative source of cash for the family through the father’s off-farm job. This scenario is similar to S1 except that the equation is satisfying servings of food instead of the specific RDAs while eliminating the milk that a heifer would provide the family. This run also mirrors S6 except that the heifer is not an animal that the family can choose to produce.

CHAPTER 4

RESULTS

The LP model was designed to illustrate the highest returns the family could expect if they followed the decisions outlined in each of the different scenarios given their initial resource endowment and opportunities to work off the farm and/or to hire labor to work on the farm. Because the basic constraints faced by the family were the resource endowment and the necessity to provide for the family's nutritional requirements. The family depicted in the study is representative for the study area. Costs and returns for the farming operation are based on estimates depicted in the enterprise budgets discussed earlier. Family household expenses (i.e, utilities, health care, and school) are also typical for the study area for a family and is similar to the representative family used for the analysis. Assumptions about the ability to work off the farm or to hire farm labor are specific to the different scenarios considered, but are consistent with conditions in the study area.

This LP is not designed to necessarily be descriptive of what a family currently does in terms of precisely what crops or livestock enterprises are produced. Rather, the scenarios are designed to facilitate observation of changes in optimal practices suggested by the model under a specific set of reasonable (achievable outcomes in the study area) circumstances assumed in each of the scenarios.

The quantities, costs, and returns for each scenario as determined by the LP are used to show the degree in which the value of the objective varies depending on which of the scenarios is being considered. The changes in these numbers for the different scenarios show the impact of the different decisions by the family on their potential economic and nutritional wellbeing. A comparison of the results for the different scenarios provides a general understanding of how different potential interventions might affect, or are affected by, other decisions by the family. Following a description of the results for scenario 1, the discussion of each subsequent scenario provides explanations of changes to employment preference, crop selection, quantity of crop selected, and over-all changes in the family's projected standard of living compared to the base scenario (scenario 1). Table one through table seven summarize the expenses and revenues, the amounts of food purchased, amounts of crops consumed, amounts of crops sold, number of animal enterprises produced, and square meters of crops grown respectively for all scenario results discussed.

Scenario 1

S1 was selected as a base scenario because it is believed that S1 is somewhat reflective of the representative small-scale farm family's actual situation. The representative family has a father working off-farm (common in the study area) and the family uses the crops they produce through the use of family labor primarily for on-farm consumption. Any excess agricultural products (above that required for consumption by the family) is sold with revenues from crop sales being used to purchase additional food at local market and to cover the family's household expenses (utilities, medical, and school). Again, a typical condition for small-scale farm families in the study area.

The objective pursued by the family is assumed to be the maximization of income (same as assumed for all of the scenarios). The LP model in this scenario selected only field crops to be grown during the year. These crops were maize (corn), potatoes, and wheat. Throughout the year, the family planted 4,812 m^2 of maize, 7,457 m^2 potatoes,

Table 7. Summary of Expenses and Revenues

	Scenarios										
	1	2	3	4	5	6	7	8	9	10	11
Objective Function	$ 2,783	$ 964	$ 499	$ 2,275	$ 3,249	$ 2,216	$ 408	$ (75)	$ 2,137	$ 291	$ 129
Working Off-Farm	$ 1,924	$ -	$ -	$ 1,994	$ 2,304	$ 1,918	$ -	$ -	$ 1,927	$ -	$ 1,922
Selling Crops	$ 2,550	$ 2,714	$ 2,228	$ 1,872	$ 3,797	$ 2,323	$ 2,498	$ 1,788	$ 2,667	$ 2,798	$ 2,487
Total Revenue	$ 4,474	$ 2,714	$ 2,228	$ 3,867	$ 6,101	$ 4,241	$ 2,498	$ 1,788	$ 4,594	$ 2,798	$ 4,409
Crop Expenses	$ (621)	$ (685)	$ (662)	$ (525)	$ (1,056)	$ (555)	$ (620)	$ (576)	$ (679)	$ (730)	$ (608)
Animal Expenses	$ 351	$ 351	$ 175	$ 175	$ 351	$ (36)	$ (36)	$ (36)	$ (11)	$ (11)	$ (397)
Purchasing Food	$ (262)	$ (258)	$ (83)	$ (83)	$ (257)	$ (275)	$ (275)	$ (93)	$ (608)	$ (608)	$ (2,115)
Family Expenses	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)
Total Expenses	$ (1,691)	$ (1,751)	$ (1,729)	$ (1,592)	$ (2,121)	$ (2,025)	$ (2,090)	$ (1,864)	$ (2,457)	$ (2,507)	$ (4,280)
Net Return to Family	$ 2,783	$ 964	$ 499	$ 2,275	$ 3,980	$ 2,216	$ 408	$ (75)	$ 2,137	$ 291	$ 129

Table 8. Total Amount of Food Purchased for the Year in 100 Gram Portions

	Scenarios										
	1	2	3	4	5	6	7	8	9	10	11
Spinach Fresh	3279	3011	366	366	3011	11040	11040	920	19597	19597	11040
Wheat Flour	975	982	1000		975				1376	1376	
Oil	108	108	108	108	108	108	108	108	108	108	108
Brown Sugar	240	240	240	240	240	240	240	240	240	240	240
Salt	5	5	5	5	5	5	5	5	5	5	5
Pepper	1	1	1	1	1	1	1	1	1	1	1
Cow Milk											14724

Table 9. The Amount of Crops Selected for Consumption in 100 Gram Portions for the Year

	Scenarios										
	1	2	3	4	5	6	7	8	9	10	11
Wheat Flour	439	421	336	338	440	414	414	414	619	619	414
Corn Flour	46	46	58	58	46	46	46	46	63	63	46
Cauliflower Cooked								190			
Carrots Fresh			110	68				94			
Spinach Fresh			29	29				92			
Tomato Fresh			31	31				94			
Celery Fresh								97			
Red Cabbage Fresh		14	204	204				188			
Broccoli Cooked			11	11	11						
Corn Cooked								767			
Potato Cooked			801	844		95	95	95			95

Table 10. Total Kilograms of Crops Sold for the Year

	Scenarios										
	1	2	3	4	5	6	7	8	9	10	11
Corn	1402	1130	1444	1976		1582	1318	779	1059	839	1457
Potato	5965	6690	5004	3486	10849	5145	5894	4374	6621	7203	5733

Table 11. Number of Animal Enterprises Selected for the Year

	Scenarios										
	1	2	3	4	5	6	7	8	9	10	11
Poultry	0	0	3	3	0	5	5	5	0	0	5
Heifer	2	2	2	2	2	2	2	2	0	0	0

Table 12. Total Square Meters of Crops Grown for the Year

	Scenarios										
	1	2	3	4	5	6	7	8	9	10	11
Corn	4812	3908	4993	6762	151	5413	4534	5600	3732	3001	4997
Potato	7457	8363	7303	5459	13561	6553	7490	5589	8276	9004	7288
Wheat	1283	1283	980	988	1286	1210	1210	1210	1810	1810	1210
Carrot			75	46				64			
Cauliflower								31			
Broccoli			3	3	3						
Spinach			7	7				23			
Celery								21			
Red Cabbage		2	33	33				30			
Green Cabbage											
Tomato			6	6				19			

and 1,283 m^2 of wheat. The farm was at full capacity, in terms of its land constraint, with all 10,000 m^2 having crops in the ground in the beginning of January, end of March, and end of December. An out-of-pocket expense of $621.00 was incurred to grow these crops. At harvest, the family chose to sell 1,402 kg of maize and 5,965 kg of potatoes. But, the family initially retained (stored) all of the wheat it produced. Selling these crops created total revenue of $2,550 for the farm family (table 6). Maize that was not sold was processed into flour and consumed in March. The wheat was selected to be stored and converted into flour for consumption from April through December.

To provide the family with protein and calcium that was not provided through the consumption of the crops the family produced, the model selected 0.14 poultry and 2.0 heifers. The model selected 0.14 poultry which is the equivalent to one chicken (a full unit of poultry consists of seven chickens). One chicken produces on average 24 eggs per month creating an excess above constraint (a minimum of 12 eggs were assumed to be consumed by the family each month through either buying them in the market or producing them though raised chickens). The two heifers supplied milk for consumption required by the family to meet calcium needs. The heifers also produce a revenue stream during the year in which each heifer produces a calf that is sold.

During both January and February, the model selected the purchase of 49 kg of wheat flour from the market. The crops grown on the family farm did not satisfy all nutrition requirements. Consequently, during each of the 12 months, the model also purchased spinach at an average of 27 kg with a spike of 31 kg in only March. Spinach was the “low-cost” source of a number of nutrients not provided from other raised or purchased sources. While the amount of spinach purchased seems unreasonable for the family's diet, it is representative of purchasing low-cost sources of missing nutrients. So, even if a constraint were placed on the amount of spinach purchased, the model would have simply selected the next cheapest source of these nutrients and "over consumed" that source also. As a result, the amount of spinach should not be considered necessarily what would be consumed by the family but rather as a representation of expenditures on the next cheapest source of the missing nutrients.

The results in Table 6 show that the father would chooses to work off-farm if the opportunity presented itself and would earn $1924 net take-home pay for doing so. This assumes that the potential employment is located within a reasonable distance for him to make the round-trip on the bus in three hours or less each day.[7] This demonstrates that it is advantageous for the father to work off-farm and to purchase food in the market. Food purchased in the market compensates for any decreased production that may have occurred by reducing family labor by the 100 hours each half-month spent in off-farm employment by the father. Even though off-farm employment was available, the father chose to work off-farm only 21 hours in the beginning of April, and 82 hours in the end of December. The decrease in April illustrates the greater return to helping the family plant potatoes than to work off of the farm at that time of the year. The December decrease in hours worked off the farm by the father is related to the labor needed on farm to plant maize that also provides a greater return than the $0.96/hour earned in off-farm employment at that particular point in the year. The family labor was fully consumed in the end of March, a surplus of 21 hours in the beginning of April, and entire amount again in all of June.

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[7] Recall that the gross monthly salary was assumed to be $300.

Scenario 2

This scenario removed the opportunity for the father to work off the farm compared to S1 in which the father could work off the farm. The field crop for selections for S2 remained the same for maize, potatoes, and wheat as they were in S1. However, S2 added a small amount of production for one of the garden varieties, red cabbage. Over the year, the family would have planted 3,908 m^2 of maize, 8,363 m^2 of potatoes, 1,283 m^2 of wheat, and 2 m^2 of red cabbage.

The farm was at full capacity, in terms of its land constraint, with all 10,000 m^2 having crops in the ground at the beginning of January, end of March, and end of December; the same as for S1. All other half-month production periods remained similar to S1 except for April, November, and the beginning of December where about 900 m^2 more cropland was planted for S2 than for S1. These additional meters are attributed to the increase in maize and potatoes planted compared to S1.

An out-of-pocket expense of $685 was incurred to grow the crops specified in S2; an increase of about $64 over out-of-pocket expenses for S1. At harvest, the family would choose to sell 1,130 kg of maize and 6,690 kg of potatoes. The family initially retains (stores) all of the wheat it produced. Selling these crops created total revenue of $2,714 for the farm family (Table 7). The quantity of maize not sold in the market but consumed by the family remains the same as for S1. The maize consumed by the family was processed into flour and consumed in March. The quantity of wheat that was selected to be stored and converted into flour for consumption from April through December did not change for S2 compared to S1.

To provide the family with protein and calcium that was not provided through the consumption of the crops the family produced, the model continued to select 0.14 poultry and 2.0 heifers just as it had done for S1.

The wheat purchased by the family only increased in January by the amount of 700 grams compared to S1. The crops grown on the family farm in S2 still did not satisfy all nutrition requirements as was the case with S1. The addition of red cabbage to the portfolio of the crops grown by the family replaced the spinach originally purchased in January in S1. But, the purchase of spinach in all the other months remained the same as it was in S1.

This scenario limited the father from working off-farm. In S1, food purchased in the market compensated for any decreased production occurring as a result of the father working off the farm for up to 100 hours each half-month. The decrease in off-farm employment in April illustrated in S1 the greater return to helping the family plant potatoes than to work off-farm at that time of the year. In this scenario (S2), planting decisions do not change much from S1, but the value of the objective function was only $964 because of the reduction in off-farm income. The increase in revenue from crops sold, and the increased expense of growing the different spread of crops in S2 than in S1 demonstrates the ability of the family to grow primarily cash crops and to continue to meet its nutritional needs. This is shown by the fact that the family's decisions about what and when to plant only marginally changed in S2 compared to S1. However, the family's standard of living, in terms of its income, decreased dramatically for S2 compared to S1.

These results demonstrate two points. First, if cash crops can be sold at the average prices specified in the model, the family will continue to choose to sell primarily cash crops and to buy food. This is because the cash crops generate enough income to buy food in the market. Second, there is a large incentive to work off of the farm if possible because the family's income will be increased dramatically compared to if no off-farm income is available to the family.

Scenario 3

This scenario removed the opportunity for the father to work-off farm and limited the food that would be purchased in the marketplace by artificially increasing the cost of purchased food by 90 times compared to S1. The field crop selection for S3 remained the same as in S1 for maize, potatoes, and wheat. However, more garden crop varieties came into the mix in S3 than in S1 with the addition of carrots, broccoli, spinach, red cabbage, and tomatoes (for quantities see Table 11). The increase in maize production and the addition of the garden crops occurred at the cost of reducing the land utilized by wheat and potatoes (compared to S1). The farm was at full capacity, in terms of its land constraint, in the same three periods as S1. Land utilization in all of the other half-month periods remained similar to S1.

The farm family's expenses to grow the crops indicated in S3 increased $42 from S1 while the revenue from crops sold decreased by $325 compared to S1. The choice of and the quantity of maize to be sold remained similar to S1 while potatoes became a storable food (not stored in S1) selection alongside wheat (stored in both S1 and S3). The potatoes were then subsequently consumed by the farm family during January through April, and again in July and December. The entire wheat harvest that the family had stored for S3 continued to provide for consumption in the form of flour for the family during April through December. But, the amount of wheat flour consumed by the farm family in S3 was less than for S1 because less land was dedicated by the farm family for wheat production in S3 than S1. Vegetables were grown throughout the year providing a wider menu selection while also providing the nutrients required by the family (see crop calendar Appendix B).

To provide the family with protein and calcium that was not provided through the consumption of the crops the family produced, the model continued to select the maximum heifers at two, but increased the production of chickens 18 times or to 2.5 units of poultry. The extra expense to raise the chickens reduced the animal income by half compared to S1.

The pantry constraint (purchase of brown sugar, cooking oil, salt, and pepper) continued to be satisfied at standard market prices (market price was not inflated for pantry items). The additional of garden crops grown replaced the need to purchase spinach in all periods except in February when the model actually selected 36 kg of spinach at the increased cost. The crops grown on the family farm continued to not satisfy all nutritional requirements for the family in all periods thus forcing this purchase.

The labor constraint for the farm family was a binding (all available farm family labor used) in the end of March, end of June, and beginning of November. The period in the beginning of April was just 18 hours short of using all family labor available during that period. However, the use of family labor in all other half-month time periods was the same as for S1. The labor required to plant the larger amounts of garden crop varieties was provided by sacrificing the growing of field crops. That is, the increased production of garden crops, which tend to be more labor intensive than cash crops on a m^2 basis, forced the transfer of family labor away from cash crops to garden types.

The standard of living for the family, as indicated by the value of the objective function, was reduced by more than $2200 (compared to S1) as a result of lost off-farm income and the need to select garden crop varieties rather than cash crops as a way to replace the purchased food allowed by S1. This scenario (S3) presents the possibility for introducing more intensive gardening methods to impoverished small-scale farmers to allow them to utilize all available family labor. This may also further support the use of genetically modified seed varieties that can be grown /planted in earlier or later periods which would allow a family like this to make better use of idle land. However, it also demonstrates that when off-farm employment is available that this strategy still does not offer a higher standard of living to the farm family than S1.

Scenario 4

This scenario provided the opportunity for the father to work-off farm but limited food purchases at the market by artificially increasing the price of purchased food by 90 times compared to S1. The LP model in this scenario selected field crops and garden crops to be grown during the year. The field crop selection for S4 remained the same as S1 consisting of maize, potatoes, and wheat. However, the planted areas for these crops were different than for S1 and were 6,762 m^2 , 5,459 m^2 , and 988 m^2 for maize, potatoes, and wheat, respectively.

Garden crop varieties came into the mix for S4 with the addition of carrots, broccoli, spinach, red cabbage, and tomatoes (for quantities see Table 12). The increase in maize production and the addition of garden crop varieties was made possible by reducing the amount of land, compared to S1, that was dedicated to growing wheat and potatoes. The farm was at full capacity, in terms of its land constraint (10,000 m^2), at the end of March and approached the limit in January. The amount of land utilized for S4 was similar to the amount of land utilized under S1 for all other periods.

An out-of-pocket expense of $525 was incurred for S4 to grow the crops described above. At harvest, the family chooses to sell 1,976 kg of maize and 3,486 kg of potatoes but initially stores all of the wheat it produced for later consumption. The selling of cash crops generates total revenue of $1,872 for the farm family (Table 7). Maize that was not sold at harvest was stored and processed into corn flour that was consumed in March. Potatoes became a storable food selection for S4 alongside wheat and were subsequently consumed during January through April, and again in July, October, and December.

Wheat was selected to be stored and converted into flour for consumption also during April through December. The farm family's expenses to grow the crops decreased $96.00 compared to S1 while the revenue from crops sold decreased by $378 compared to S1. The choice to grow and the amount of maize sold was significantly higher for S4 than for S1 (almost 2,000 m^2 more) which was land used to grow potatoes and wheat in S1. For S4, vegetables were grown throughout the year presenting a wider menu selection for the family than other scenarios while providing the nutrients required for the family. The selection of vegetables for S4 was similar to the quantities and selection for S3, except for carrots which had only half as many produced under S4 as under S3.

To provide the family with protein and calcium that was not provided through the consumption of the crops the family produced, the model continued to select the maximum number of heifers at two, but increased the production of chickens by 18 times compared to S1 or 2.5 poultry units. The extra expense to raise the chickens reduced the animal income by half of what it was for S1.

The pantry constraint continued to be satisfied at standard market prices (the inflated prices for purchased food did not apply to pantry items which could continue to be purchased at regular market prices). The garden crops that were grown under S4 replaced the previously purchased spinach (e.g. S1) in all periods except during February. The model selected 36 kg of spinach even at the greatly inflated cost. The crops grown on the family farm simply did not satisfy all nutritional requirements for all periods for the family thus forcing the model to purchase spinach.

The results in table 7 for S4 show that the father would chooses to work off-farm if the opportunity presented itself and would earn $1994 net annual take-home pay for doing so. Even though off-farm employment was available, the father continued to choose to work off-farm only 48 hours in the beginning of March, 81 hours in the beginning of April, three hours in the beginning of June, no hours at the end of June, and 46 hours in the end of December. The choice to decrease off-farm labor hours in April and June illustrates that there was a greater return to helping the family plant potatoes than there was to work off-farm at that time of the year. The March and December decrease in hours worked off-farm by the father is related to the labor needed on farm to plant maize indicating that labor spent planting maize also provides a greater return than the $0.96/hour earned in off-farm employment at that particular point in the year. Even though the father chose to work on-farm during many of the half-month periods, family labor was constrained only in the month of June. This suggests that the necessary farm work is able to be completed by the family members except during the times mentioned above when the father helps with planting and harvesting of cash crops.

This demonstrates that it is advantageous for the father to work off-farm even when the ability to purchase food in the market is limited. This is a scenario in which a family is striving to be self-sufficient in what they produce which would limit the dependence on the local market. The standard of living has been reduced by $508 compared to S1 because the family is forced to grow the food the family needs which cannot be purchased in the market for a reasonable price. When facing an increased need to satisfy the family nutritional needs from crops grown on the farm, the family's choice appears to favor cash crops that require the less amounts of labor compared to other crops. Potatoes may produce a higher return, but require more labor while not satisfying nutritional constraints in the same way that maize does.

This scenario illustrates a family that is attempting to eliminate food purchases and be self-sufficient on their small-scale farm. It could also be viewed as a scenario representing a family that is located in an area that does not have a local market to purchase food at a reasonable price, but the father does have the ability to work at a job off the farm that generates a reasonable income (could be honey harvesting, charcoal making, or another income generating activity in a rural area as well as commuting to work for wages in a nearby small city). If satisfying nutritional requirements is impossible with on-farm food production, the model allows food purchases at premium prices which allows the model to solve (i.e., satisfy all constraints including the nutritional constraints of the family). This scenario also provides a comparison of crop selections to S3 when the available on-farm family labor is reduced while producing a higher standard of living than for S3 while being more self-sufficient.

Scenario 5

This scenario allowed the father to work off farm and also allowed the farm family to hire labor should the need arise. Food was allowed to be purchased at regular market prices to meet nutritional needs if food produced and consumed on the farm was not sufficient to meet nutritional needs (less expensive sources of food to meet nutritional needs could be purchased than if it were raised on the farm).

The LP model in this scenario selected the same field crops to be grown as S1 did. However, the amount of field crops produced by the farm family changed quite drastically from S1 in terms of the number of m^2 planted. Throughout the year, the family planted only 151 m^2 of maize, but there was an immense increase in potatoes produced (compared to S1) to 13,561 m^2 potatoes. The amount of wheat planted, 1,286 m^2, was similar to S1. The model also selected a small amount of broccoli to be produced on the farm (similar to S3 and S4). The land on the farm was planted to near its full capacity throughout the year with all 10,000 m^2 having crops in the ground in every period except during the period from the end of January through the beginning of March (only about half of the available land is used during that particular part of the year).

An out-of-pocket expense of $1056 was incurred to grow the crops specified above for this scenario. The family was able to sell almost 11,000 kg of potatoes and consumed the small maize harvest they had during March in the form of corn flour. The level of consumption and storage of wheat produced for S5 mirrored that of S1. Selling the potatoes harvested created total revenue of $3,797 for the farm family (Table 7). To provide the family with protein and calcium that was not provided through the consumption of the crops the family produced, the model continued to select 0.14 poultry and 2.0 heifers just as it had for S1.

During both January and February, the model selected to purchase 49 kg of wheat flour from the market as it had for S1. The crops grown on the family farm did not satisfy all nutrition requirements of the family. Consequently, the model also purchased spinach at an average of 27 kg per month, a spike of 31 kg in only March, and no spinach in September. In S1, purchased spinach was the "low-cost" source of a number of nutrients not provided from other raised or purchased sources. However, broccoli became the low-cost source of missing nutrients when family labor is reduced because of off-farm employment but non-family labor can be hired at $0.625/hr.

The results in Table 6 show that the father would choose to work off-farm if the opportunity presented itself and would earn $2304 net take-home pay for doing so. Since the father receives a higher wage than what replacement labor costs, the LP has the father working off farm in all periods in this scenario and the family has hired labor to satisfy the increased labor needs presented by expanding their potato crop. The hired labor expense was $732 but resulted in contributing to an increase in crop revenue of $1,247 compared to S1. Allowing the family to hire non-family labor also allowed the father to work additional hours off-farm compared to S1 which provided the family with $380 more income than S1 thus contributing to a better standard of living for the family. This demonstrates that it is advantageous for the father to work off-farm with the assumption that the hired worker would be able to complete the tasks with at least the same efficiency as the father and that the labor provided by other family members would not be reduced to satisfy due to the need for family members other than the father taking over managerial responsibilities.

Food purchased in the market for S5 is equal to S1, except in September. Spinach was not purchased as it was in S1 due to nutritional requirements being satisfied with broccoli that was grown on the farm instead. Previously it was stated that it is beneficial to hire labor that the father cannot provide (because he is working off of the farm) to assist in producing field crops that are sold for cash. However, it appears that it may also be advantageous for the farm family to grow at least a few vegetables, in this case broccoli, to satisfy the family's nutritional requirements.

This scenario illustrates an entrepreneurial family where the father could work off-farm while the family employs replacement labor to satisfy on-farm production needs. The family situation described in this scenario may reflect opportunities in the community of Cochas, but these practices described in the scenario are not generally practiced by farmers in the community. It is possibly due to the capital and credit restraint that producing such a cash crop requires from inputs and increased labor which a cash poor rural family rarely has access to. From the information gathered in conversations with farm families in Cochas, the absence of this type of entrepreneurial small-scale farm activity may be a function of the families being extremely risk adverse and who do not desire to transfer so much risk to one crop (potatoes).

The results for this scenario demonstrate the important tradeoffs which exist between working off the farm and subsistence farming (growing primarily for the farm family's own consumption). While higher standards of living can be achieved by emphasizing cash crops and also working off the farm, there may also be risks associated with this strategy. Observation within the community of Cochas seems to support the idea of a mixed strategy where people choose to diversify activities as well as work off farm. This is consistent with portfolio theory but also suggests that risk-reducing activities such as better infrastructure, irrigation systems, and fertilizer would tend to raise living standards in the study area.

Scenario 6

The sixth scenario is designed to fulfill MyPlate serving requirements in lieu of the “normal” nutritional constraint. It is a mirror of S1 except that the nutritional constraint equation in the LP is set to satisfying servings of food groups instead of the specific RDAs used in S1-S5.

The LP model in this scenario continued to select only field crops to be grown during the year as it had for S1. These crops were the same as S1; maize, potatoes, and wheat. The farm family planted 5,413 m^2 of maize, 6,553 m^2 potatoes, and 1,210 m^2 of wheat. This equates to an increase, compared to S1, in maize production at the expense of potato and wheat production.

The farm’s field capacity, in terms of how much land was in production during each one-half month production period in this scenario, was similar to S1 for all 12 months. An out-of-pocket expense of $555 was incurred in this scenario to grow these crops; $66 less than in S1. At harvest, the family chose to sell 1,582 kg of maize and 5,145 kg of potatoes. The family maintained, as it is in S1, the practice of initially storing all the wheat produced on the farm. The crops that were sold in this scenario created total revenue of $2,322 for the farm family, a reduction of $227 compared to S1 (Table 7). The maize that was not sold but was rather processed into flour for consumption in March remained the same for S6 as it was for S1. The selection of wheat to be stored and converted later into flour for consumption during April through December was reduced by 3 kg monthly compared to S1.

To provide the family with the number of servings needed to satisfy MyPlate, the model selected 5.33 poultry and 2.0 heifers. The selected 5.33 poultry is the equivalent to 37 chickens (a full unit of poultry consists of seven chickens). One chicken produces on the average 24 eggs per month. Consequently, approximately 1,000 eggs were produced each month from the 37 chickens, which were used to create a least-cost ration to satisfy the number of meat/protein servings specified in MyPlate. The high level of chicken production in this scenario reduced the income from animals reported for S1 and now shows an expense for S6 of $36. The calves are still being sold, but the increased cost of the poultry enterprise has more than depleted the revenue from the heifer enterprise.

Wheat flour was eliminated from food purchases (compared to S1) but the crops grown on the family farm did not satisfy the MyPlate serving requirements. During each of the twelve months, the model purchased 92 kg of spinach, 3.4 times what the model selected for S1 (regular RDA nutritional constraints). The amount of spinach purchased is unreasonable for the family's diet and it must be remembered that it is representative of purchasing low-cost sources of missing nutrients. Should a constraint be placed that limited these types of purchases, it would only increase the cash outlay by the family and further reduce their standard of living.

The results in Table 7 depict that the father would choose to work off-farm if the opportunity presented itself and would earn $1918 net take-home pay for doing so. This is very similar to S1 and is only less due to the difference in S6 by a few additional hours that were selected by the model for on-farm work to support increased maize production (after accounting for the decrease in potato production).

Subjecting a farm family in the developing world to the nutritional guidelines presented in MyPlate would decrease the standard of living for the family. The estimated reduction to the standard of living is $560 compared to S1. This suggests that the MyPlate guidelines are not well suited for a developing world situation. North American diets tend to over consume certain food groups resulting in too much saturated fat and carbohydrates in diets. In the developing world, this is much less of a problem because nutrition targets seem less complex, i.e., enough calories and enough protein, compared to North American diets where incomes are larger and diet problems are different than in the developing world.

Scenario 7

This scenario removed the opportunity for the father to work-off farm (S6 allowed the father to work off of the farm) while maintaining the diet constraint of MyPlate. As such, this scenario is the same as S2 except for the MyPlate requirements imposed on S7 compared to the RDA nutritional requirements imposed on S2.

The LP's field crop selections remained the same as for S2 and S6 with maize, potatoes, and wheat being produced by the farm family. However, this scenario did not incorporate the small amount of red cabbage that was produced on the farm in S2. Throughout the year in this scenario, the family planted 4,534 m^2 of maize, 7,490 m^2 of potatoes, and 1,210 m^2 of wheat. These are comparable changes in production rates from S6 and mirror the percentage changes in production from S1 to S2 production levels.

The land planted on the farm was at full capacity, in terms of its land constraint, with all 10,000 m^2 having crops in the ground in the beginning of January, end of March, and end of December; the same as for S1 and S6. An out-of-pocket expense of $621 was incurred to grow these crops, an increase of about $66 above the same expense for S6 but equal to S1. At harvest, the farm family chose to sell 1,318 kg of maize and 5,894 kg of potatoes. But, the family initially retained (stored) all of the wheat it produced. Selling these crops created total revenue of $2,714 for the farm family (Table 6). The quantity of unsold (stored) maize remained the same and it was processed into flour and consumed by the farm family in March. The quantity of wheat that was selected to be stored and converted into flour for consumption from April through December did not change from S6.

To provide the family with the number of servings needed to satisfy MyPlate, the model selected 5.33 poultry units and 2.0 heifers. The increased level of chicken production reduced the income from animals compared to S1, and now shows the expense of $36.00 which is equal to S6. The calves are still being sold, but the increased cost of the poultry enterprise has depleted the revenue as in S6.

Wheat flour was not purchased from the market but the crops grown on the family farm continued, just as in S6, not to satisfy serving requirements specified in MyPlate for the farm family. During each of the twelve months, the model purchased 92 kg of spinach, 3.4 times what the model selected under nutritional constraints (S2). The amount of spinach purchased is unreasonable for the family's diet and it must be remembered that it is representative of purchasing low-cost sources of missing nutrients.

Should a constraint be put in place that limited these types of purchases, it would only increase the cash outlay by the family and further reduce their standard of living.

In this scenario (S7), planting decisions do not change much from S1, but the value of the objective function was only $408 compared to $2,216 for S6. This was due primarily to the reduction in off-farm income compared to S6. The relationship of changes in crops planted, sold, and consumed between S7 and S6 is approximately equal to the changes between S2 and S1. The increase in revenue from crops sold, and the increased expense of growing the different spread of crops in S7 compared to S1 demonstrates the ability of the family to grow primarily cash crops and to continue to meet its nutritional needs. This supports the notion that the farm family can have a higher standard of living, even with no off-farm income, if it can sell cash crops and buy food rather than raising vegetables for on-farm consumption only. This is shown by the fact that the family's decisions about what and when to plant only marginally changed in S7 compared to S1. However, the family's standard of living, in terms of its income, decreased dramatically for S7 compared to S1.

The drastic change in the objective function from S1 to S7 can be explained by the removal of off-farm in S7 compared to S1 and the reduction in crop revenue in S7 compared to S1 due to the "MyPlate Tax" (the need to meet MyPlate serving requirements is more expensive for the family than simply meeting RDA requirements).

Even though the family had the more costly constraint of MyPlate to satisfy in S7 compared to S1 (simple RDA requirements), the family continued to select field crops which require less labor than the garden crop varieties that tend to be more labor intensive on a m^2 basis than field crops. The revenue from the sale of field crops is able to satisfy the different constraints (food purchase needed) on food groups specified in MyPlate while also providing a cash crop to create revenue for the family to purchase other foods in the market when allowed.

The results for this scenario illustrate that, given reasonable risks; it pays the farm family to grow cash crops rather than producing vegetables and livestock products only for on-farm consumption. This seems to suggest that as long as a reasonably well-functioning market exists it may be difficult to recruit farm families into interventions that attempt to emphasize vegetable production for on-farm consumption. Of course, price risk for cash crops is an important consideration. Consequently, it is likely best for vegetable-oriented interventions to start slowly with farm families in the study area by encouraging them to plant only small plots of vegetables rather than expecting farm families to convert a significant amount of land currently devoted to field crops into diversified vegetable production for on-farm consumption.

Scenario 8

In addition to replacing the nutrition constraint (RDAs) with MyPlate, this scenario does not allow father to work-off farm and limited food purchases in the marketplace by artificially inflating the cost to purchase most food items by 90 times compared to S1. The LP’s selection of field crops produced for S8 remained the same as for S1 and included maize, potatoes, and wheat.

In response to the model limiting off-farm food purchases, and having a greater supply of family labor available due to the father not working off-farm, the quantities of field crops changed from S6 and S7. In general fewer potatoes are produced (with the exception of S4) but lightly more corn (again with the exception of S4) compared to the other scenarios already discussed. Maize production was selected to increase by 788 m^2 while potatoes decreased by 1,868 m^2 compared to S1. Wheat only marginally changed compared to S1 (down to 1,210 in S7 compared to 1,283 in S1) as occurred in the other MyPlate scenarios (S6, S7).

Garden crop varieties are significantly expanded compared to the other scenarios with S8 devoting the largest land area to garden crops of any of the scenarios considered. This included additional carrots, cauliflower, spinach, celery, red cabbage, and tomatoes (for quantities see Table 12). The increase in maize production and the additional garden crops occurred at the cost of reducing the land utilized by wheat and potatoes (compared to S1). The farm was at full capacity, in terms of its land constraint, in only the half-month period of the end of March which is when the planting season for both maize and potatoes co-exist. Land utilization in all of the other half-month periods was reduced on the average compared to those in S1. The farm family sells its excess corn and potato production.

The farm family's expenses to grow the crops indicated in S8 decreased $45 from S1 while the revenue from crops sold decreased by $762 compared to S1. The choice of and the quantity of maize and potatoes to be sold were reduced but a larger quantity of these crops was stored than in any of the other scenarios considered.

This was the first scenario in which the model chose to store any amount of maize and it selected to store a relatively large amount of maize; 1,544 kg. Stored potatoes were subsequently consumed by the farm family during January, while the maize was available July through November to be converted into corn flour and consumed by the farm family. The entire wheat harvest that the family had stored for S8 continued to provide for consumption in the form of flour during the period of April through November. But, the amount of wheat flour consumed by the farm family in S8 was less than for S1 because less land was dedicated by the farm family for wheat production in S8 than S1. Vegetables were grown throughout the year providing a wider menu selection while also providing the nutrients required by the family (see crop calendar Appendix B).

To provide the family with the number of servings needed to satisfy MyPlate in terms of protein/meat, the model selected 5.33 poultry units and 2.0 heifers. The selected 5.33 poultry units is equivalent to 37 chickens (a full unit of poultry consists of seven chickens). One chicken produces on average 24 eggs per month, or 1,000 eggs from 37 chickens, meaning that eggs produced on the farm were a least-cost form of meat/protein servings available to meet the requirements specified in MyPlate. The increased level of egg production in S8 reduced animal income compared to S1 (shows an expense of $36). The calves are still being sold, but the increased cost of the poultry enterprise has more than depleted the revenue generated by the heifer enterprise.

The pantry constraint (purchase of brown sugar, cooking oil, salt, and pepper) continued to be satisfied at standard market prices (market price was not inflated for pantry items). Wheat flour was eliminated from the foods purchased (S1) in the market, but the crops grown on the family farm continued not to be able to fully satisfy serving requirements specified by MyPlate.

The additional of garden crops grown by the farm family under S8 replaced the need to purchase spinach in all periods except in February when the model purchased 92 kg of spinach, 3.4 times more than what the model selected under nutritional constraints

(RDAs) for the same period in S1. The amount of spinach purchased is unreasonable for the family's diet and it must be remembered that it is representative of purchasing low-cost sources of missing nutrients. Should a constraint be put in place that limited these types of purchases, it would only increase the cash outlay by the family and further reduce their standard of living.

The labor constraint for the farm family was binding (all available farm family labor used) in the end of March, end of June, and beginning of November. The period in the beginning of April was just 13 hours short of using all family labor available during that period. However, the use of family labor in all other half-month time periods was less on the average than what the farm family could provide. The labor required to plant the larger amounts of garden crop varieties selected in S8 compared to the other scenarios was provided by sacrificing the growing of field crops. That is, the increased production of garden crops, which tend to be more labor intensive than cash crops on a m^2 basis, forced the transfer of family labor away from cash crops to garden crop types.

The standard of living for the family, as indicated by the value of the objective function, was reduced by more than $2800 (compared to S1) as a result of lost off-farm income and the need to select garden crop varieties rather than cash crops as a way to replace the purchased food allowed by S1. This scenario (S8) presents the possibility for introducing more intensive gardening methods to impoverished small-scale farmers to allow them to utilize all available family labor. This may also further support the use of genetically modified seed varieties that can be grown /planted in earlier or later periods which would allow a family like this to make better use of idle land. However, it also demonstrates that when off-farm employment is available that this strategy still does not offer a higher standard of living to the farm family than S1.

This scenario suggests that farm families in the study area could almost achieve the MyPlate nutritional requirements if they are forced to do so (no off-farm income and no access to reasonably-priced food). However, they would be able to do so only by accepting a greatly reduced standard of living if normal opportunity costs are assumed (i.e., ability to work off the farm for wages). This implies that opportunity costs are extremely important to consider when developing interventions involving switching field crops production to expanded vegetable production for on-farm family consumption. It also suggests that such interventions will likely best be suited for areas that are at a considerable distance from urban center where off-farm employment might be available. Also, other types of off-farm income (e.g., honey harvesting, charcoal production) also must be limited for farm families to be willing to switch out field crops for significant amounts of vegetable production for on-farm consumption.

Scenario 9

Scenario 9 is meant to illustrate a family that does not possess or have access to the capital required to purchase a lactating cow that births one calf per year, or a family that does not have sufficient cash flow to purchase a calf and maintain her till producing age. This scenario mirrors S1 except that the heifer is not an animal that the family can choose to produce. It also means that the nutrients provided by the milk from the cow are not available for on-farm consumption by the family.

The LP model in this scenario selected only field crops to be grown during the year (no garden crop varieties selected to be grown in this scenario). The crops selected to be produced on the farm were maize, potatoes, and wheat. During the year, the family planted 3,732 m^2 of maize, 8,276 m^2 potatoes, and 1,810 m^2 of wheat.

The farm was at full capacity, in terms of its land constraint, with all 10,000 m^2 having crops in the ground for the same half-month periods as S1. Each half-month period had more m^2 planted than in S1 except the half-month periods during the end of January through the end of March with each of these periods having 266 m^2 or less planted. This is in direct relation to the additional potato crops planted throughout the year, specifically the 266 m^2 planted in June and harvested in the beginning of January. An out-of-pocket expense of $679 was incurred to grow these crops, $59 more than S1.

At harvest, the family chose to sell 1,059 kg of maize and 6,621 kg of potatoes. The family initially retained (stored) all of the wheat it produced as in S1 even though the family planted 527 m^2 more in S9 than for S1. Selling these crops created total revenue of $2,667 for the farm family (Table 7). Maize that was not sold was processed into flour and consumed in March; the same as for S1. The wheat was selected to be stored and converted into flour for consumption from April through December which also was the case in S1. But, S8 produced larger quantities of wheat than the other scenarios due to the increased harvested area for wheat (largest wheat area harvested of all the scenarios).

In S1, the model selected 0.14 poultry and 2.0 heifers to provide the family with protein and calcium that was not provided through the consumption of the crops the family produced. Without the option of selecting a heifer, the poultry selection and quantity remained unchanged in S8 from S1. However, without the heifer the farm family did not have access to an inexpensive source of calcium nor the revenue stream generated during the year from the heifer's calves being sold. Thus, the animal expense for the year was only $11 and went toward raising the chicken.

During both January and February, the model selected the purchase of 69 kg of wheat flour from the market, 20 kg more than in S1. The crops grown on the family farm did not satisfy all nutrition requirements. With all other constraints held constant except for eliminating the heifer from S1, the S8 model purchased spinach at an average of 162 kg per month. Spinach was the "low-cost" source of a number of nutrients not provided from other raised or purchased sources. Without milk, spinach proves to be a lower-cost source of calcium than purchasing milk from the store. While the amount of spinach is unreasonable for the family's diet, it is representative of purchasing low-cost sources of missing nutrients. So, even if a constraint were placed on the amount of spinach purchased, the model would have simply selected the next cheapest source of these nutrients and "over consumed" that source also. As a result, the amount of spinach should not be considered necessarily what would be consumed by the family but rather as a representation of expenditures on the next cheapest source of the missing nutrients.

The results in Table 7 show that the father would choose to work off-farm if the opportunity presented itself and would earn $1927 net take-home pay for doing so. This minimal increase in income compared to S1 is due to the labor hours saved on farm from not caring for the heifers but instead is utilized to grow cash crops. S8 continues to demonstrate that it is advantageous for the father to work off-farm and to purchase food in the market as in S1. The family labor was fully consumed in the same half-month periods as S1.

Although a family may dedicate more time to growing cash crops when not required to care for a heifer, the decrease in the standard of living compared to S1 (objective function value is $646 less for S9 than for S1) cannot be offset by selling more cash crops. In addition, the food expenditure was over 2.5 times the expenditures on food projected for S1. This scenario supports what Heifer International has done for years in providing a low-cost and relatively low input source of calcium that could also provide revenue streams if their model did not dictate gifting the born calves to neighbors or family members.

This scenario provides strong evidence for the importance of raised animal protein and calcium sources that are raised on the farm. Most farm families in the study area have cows and chickens. The results for this scenario underscore the important role animals play in the nutritional and economic wellbeing of these farm families.

Scenario 10

This scenario removed the opportunity for the father to work off the farm compared to S1 in which the father could work off the farm. This scenario also eliminates the heifer from the farm animal set. This are the only difference in S10's (no heifer) constraints compared to S2.

The LP's selection of field crops for S10 remained the same as the other scenarios by selecting maize, potatoes, and wheat to be produced on the farm. However, S2 added a small amount of production for red cabbage which S10 did not. No garden crop varieties were selected although S10 shares the constraints of S2 of not allowing the father to work off-farm. However, food products may be purchased at the local market at regular market prices.

Over the year, the S10 farm family would have planted 3,001 m^2 of maize, 9,004 m^2 of potatoes, 1,810 m^2 of wheat. The S10 quantities selected of maize are 1,811 m^2 less than S1, and 907 m^2 less than S2 quantities. Potatoes were produced in the largest amount of all scenarios thus far considered that did not allow for the hiring of non-family labor.[8] This scenario (S10) selected 1,547 m^2 of potato production more than S1 and 641 m^2 more than S2 (S2 is the next highest in potato production). Wheat production levels are equal to S9 with 1,810 m^2 being produced (also exceeds the amount of wheat produced in S1).

The farm was at full capacity, in terms of its land constraint, with all 10,000 m^2 having crops in the ground at the beginning of January, end of March, and end of December; the same as projected for S1 and S2. Each half-month period in S10 had more m^2 planted than in the same periods corresponding to S1 with the exception of the half-month periods from the end of January through the end of March (this was the same pattern observed in S9 compared to S1 which illustrates a greater use of land for all the year when no heifer is on the farm).

An out-of-pocket expense of $730 was incurred to grow the crops specified in S10; an increase of about $109 over out-of-pocket expenses for S1. At harvest, the family would choose to sell 839 kg of maize and 7,203 kg of potatoes. The farm family initially retained (stored) all of the wheat it produced (same as in S1) even though the family planted 527 m^2 more in S10 than S1; the same practice was evident in S9.

Selling these crops generated total revenue of $2,798 for the farm family (table 7). The quantity of maize not sold in the market but consumed by the family remains the

[8] Recall that only scenario 5 allowed the hiring of off-farm labor for production for an entrepreneurial family.

same as for S1. The maize consumed by the family was processed into flour and consumed in March. The farm family elected to store the wheat it produced which was subsequently converted into flour for consumption during the period of April through December (same practice as in S1 but S10 had the family produce more wheat than it did for S1).

In S1, the model selected 0.14 poultry units (one chicken) and 2.0 heifers to provide the family with protein and calcium that was not provided through the consumption of the crops the family produced. Without the option of selecting a heifer, the poultry selection and quantity remained unchanged in S10 from S1. Without the heifer, the family did not have access to an inexpensive source of calcium nor the revenue stream during the year from the heifers' calves being sold. Thus, the animal expense for the year was $11 used only to raise the chicken.

As in S9 (also no heifers on the farm) in both January and February the model selected the purchase of 69 kg of wheat flour from the market; 20 kg of wheat more than in S1. The crops grown on the family farm did not satisfy all nutrition requirements. With all other constraints held constant except for eliminating the heifers from S1 and not allowing off-farm income, the S10 model purchased spinach at an average of 162 kg per month, with a spike of 181 kg in March which also occurred in S9. Without the milk production on farm, spinach proves to be a lower-cost source of calcium than purchasing milk from the store with a selected quantity in S10 over six times the quantities selected in S1. The amount of spinach should not be considered what would be consumed by the family but rather as a representation of expenditures on the next cheapest source of the missing nutrients. This simply means that without the milk produced by the cow that the farm family will seek to purchase the next lowest-cost source of calcium and protein, in this case spinach.

This scenario limited the father from working off-farm. In S1, food purchased in the market compensated for any decreased production occurring as a result of the father working off the farm for up to 100 hours each half-month. The decrease in off-farm employment in April illustrated in S1 the greater return to helping the family plant potatoes than to work off-farm at that time of the year. In this scenario (S10), planting decisions changed drastically for the cash crops compared to S1, but the value of the objective function was only $290 (compared to $2,783 for S1) because of the reduction in off-farm income in S10 compared to S1 and the increase in purchased food expenditures in S10 compared to S1 because no milk is produced on the farm.

The increase in revenue from crops sold, and the increased expense of growing the different spread of crops in S10 than in S1 demonstrates the ability of the farm family to grow primarily cash crops to meet its nutritional needs. This is shown by the fact that the family’s decisions about what and when to plant only marginally changed in S10 compared to S1, while the quantities of crops produced changed greatly. However, the family’s standard of living, in terms of its income, decreased dramatically for S10 compared to S1.

If cash crops can be sold at the average prices specified in the model, the family will continue to choose to sell primarily cash crops and to buy food rather than to greatly expand the amount of vegetables it goes for on-farm consumption. This is because the cash crops generate enough income to buy food in the market. Second, there is a large incentive to work off of the farm if possible because the family’s income will be increased dramatically (S1) compared to if no off-farm income is available to the family (S10).

Scenario 11

The eleventh and final scenario considered is similar to S1 except that the nutritional constraint used in the LP satisfies the serving requirements for food groups as specified in MyPlate, instead of the specific RDAs used in S1-S5. This scenario mirrors S6 except that the heifer is not an animal that the family can choose to produce.

The LP model in this scenario continued to select, as with S10, only field crops to be produced during the year (no garden crop varieties selected). S11 field crop plantings were only marginal different from those planted in S1. The field crops for S11 were the same as for S1; maize, potatoes, and wheat. Under S11, the farm family planted 4,997 m^2 of maize, 7,288 m^2 potatoes, and 1,210 m^2 of wheat. This equates to an increase, compared to S1, in maize production at the expense of potato and wheat production. This is a similar shift in crop selection as when S1 was compared to S6. However, the shift was a bit greater for S6 than for S11.

The farm's field capacity, in terms of how much land was in production during each one-half month production period in this scenario, was similar to S1 for all 12 months. This further establishes the tradeoff stated earlier between corn production with potatoes and wheat. An out-of-pocket expense of $608 was incurred in this scenario to grow these crops; $13 less than in S1. At harvest, the family chose to sell 1,457 kg of maize and 5,733 kg of potatoes. The family maintained, as it did in S1, the practice of initially storing all the wheat produced on the farm.

The crops sold in this scenario created total revenue of $2,487 for the farm family, a reduction of $63 compared to S1 (Table 7). The maize that was not sold but was rather processed into flour for consumption in March remained the same for S11 as it was for S1 and S6. The selection of wheat to be stored and converted later into flour in S11 is the same as S6 with a reduction of 3 kg monthly compared to S1 during April through December.

To provide the family with the number of servings needed to satisfy MyPlate, the model selected 5.33 poultry units. The 5.33 poultry units are the equivalent of about 37 chickens (a full unit of poultry consists of seven chickens). S11 mirrors S6 in that the model selected the same level of chickens. The 37 chickens produce about 1,000 eggs which were used by the farm family to create a least-cost ration to satisfy the number of meat/protein servings specified in MyPlate. The high level of chicken production in this scenario, compared to many of the other scenarios, reduced income from animals compared to S1 (now an expense of about $11 per chicken). Without the presence of the heifers in the model that produce revenue by selling the calves, the increased cost of the poultry enterprise has created another financial strain on the family when it is forced to satisfy the MyPlate constraint.

Wheat flour was eliminated from food purchases (compared to S1) but the crops grown on the family farm did not satisfy the MyPlate serving requirements. During each of the twelve months, the model purchased 92 kg of spinach, 3.4 times what the model selected for S1 (regular RDA nutritional constraints were assumed for S1). The amount of spinach purchased is unreasonable for the family's diet and it must be remembered that it is representative of purchasing low-cost sources of missing nutrients. Should a constraint be placed that limited these types of purchases, it would only increase the cash outlay by the family and further reduce their standard of living.

Without the milk producing heifer, and if the family is subjected to meeting a required daily intake of the dairy food group in MyPlate, the model selects 123 kg of purchased milk (about 120 liters) each month which increased the food expense to $2115 for the year. This is over double what the families in the surveyed area reported as their budget for purchased food was.

The results in table 6 depict that the father would choose to work off-farm if the opportunity presented itself and would earn $1921 net take-home pay for doing so. This is very similar to S1 and is a value only less than S1 as a result of S11 using a few additional hours (compared to S1) to support increased maize production (after accounting for the decrease in potato and wheat production).

Subjecting a farm family in the developing world to the nutritional guidelines presented in MyPlate would decrease the standard of living for the family. The estimated reduction to the standard of living is $2654 compared to S1 which is accredited to the elimination in the model of the milk producing heifer while continuing to require the farm family in Ecuador to consume dairy products at a developed world rate. This suggests that the MyPlate guidelines are not well suited for a developing world situation. North American diets tend to over consume certain food groups resulting in too much saturated fat and carbohydrates in diets. In the developing world, this is much less of a problem because nutrition targets seem less complex, i.e., enough calories and enough protein, compared to North American diets where incomes are larger and diet problems are different than in the developing world.

The results for S11 reinforce the importance of livestock, and especially heifers in this case, to the overall nutritional and economic wellbeing of families in the study area. Opportunity costs, in terms of the ability to work off of the farm are also demonstrated to be a very important consideration when considering interventions in the study area.

Synthesis of Scenarios

The results demonstrate clearly the need to integrate different aspects of a small-scale farm family's lives into whole-farm decision making frameworks. The different scenarios provided illustrate how the economics of the farm family have ties to nutritional goals and vice versa.

Observation by the author in the study area showed that the generally accepted practice of farm families there is have the father work off farm. However, when planting and harvesting of cash crops is taking place on the farm, the father will work more hours on the farm and fewer hours off of the farm than typical. They do this because the farm families perceived it to be more beneficial than working off the farm all of the time. This implies essentially that the value of cash crops to the family is high enough that it pays to work fewer hours off the farm during planting and harvest to care for these crops rather than relying solely on off-farm income for the family's livelihood. However, it is clear that off-farm income is extremely important to the standard of living these families are able to achieve. The return to labor of off-farm income has in no way attempted to adjust for social dimensions or risk that may be associated with the father working away from the family farm for extended periods of time

The entrepreneurial family (S5) illustrates that even on a small scale that it is better for the father to work off-farm and pay a day laborer to complete the work he would have done by staying home. It is interesting that even if the father does not work off of the farm that there are not large changes in the types of crops produced unless the amount of food purchased in the market is severely limited. This demonstrates the importance of cash (field) crops to the farm family. It also shows that there are only a few times during the year when the farm family's labor constraint is reached (all available family labor is used). So, essentially, much of the father's time spent working off the farm is relatively slack with the exception of when planting and harvesting are taking place for the field crops (especially potatoes and maize). During those busy periods, the father will choose to work on the farm rather than off the farm for short periods illustrating again the importance of the cash crops to the farm family.

Even in the scenarios when no off-farm income is available, the increased supply of 100 hours each half-month of family labor gained by the father not working off the farm is not used to greatly expand the amount of crops that are grown. This is related to the fact that the farm is mostly at its planting capacity with or without off-farm income, so just increasing the amount of family labor available does not lead to much more crop production on the part of the farm family. This suggests a relatively low opportunity cost exists for the father to work off of the farm, but conversely, that a relatively high opportunity cost exists for the father's off-farm labor.

When a family is forced to grow the food they need due to inflated market prices for purchased food, the farm family will increase the types and amounts of vegetables it produces on the farm. However, the family's standard of living (measured by cash income) will be greatly reduced compared to if the family concentrates on producing and selling field crops while purchasing any needed food. Each scenario supports the claim that it is better to work off-farm than staying home, especially if staying home means attempting to create a self–sufficient farming operation.

Diverting resources away from producing field crops to producing small-scale garden crop varieties is only justifiable if virtually no opportunity costs for farm family labor exist (no off-farm employment opportunities) and if food cannot be purchased at a reasonable price. This is also true if cash crops can be planted, harvested, and sold instead of focusing on garden crops for on-farm consumption. A higher standard of living can be achieved for the farm family in this case (focus on field crops rather than vegetables for on-farm consumption) even if no off-farm income is available.

The results imply that opportunity costs are extremely important to consider when developing interventions involving switching field crop production to any other enterprise. This is particularly relevant when considering expanded vegetable production for on-farm family consumption. It also suggests that such interventions (switching field crops for vegetable crops) will likely best be suited for areas where farmers are a considerable distance from urban centers (no off-farm employment opportunities available) or where field crop producers face large price or production risks. However, even in isolated locations other types of off-farm income (e.g., honey harvesting, charcoal production) may improve livelihoods of poor farm families more than striving to become self-sufficient in crop production for consumption. This is a testable hypothesis, of course.

The results demonstrate how important animals are in achieving nutritional goals for the farm family. Cows in general are considered the most inefficient animal when measuring feed conversion to meat yield, but when one contemplates adding a milk producing heifer to a poor rural farmer, the results of this study suggest it is a benefit to the farm family. The cow provides a food source that requires minimal amounts of labor (at least in this study area) because it can be sustained with crop residue and wild-growing forage. The results for the scenarios that had animal enterprises available as compared to those in which the heifer was eliminated underscored the important role animals play in the nutritional and economic wellbeing of these farm families.

The results indicate that, on the average, the representative farm family in this rural, small-scale farming community can achieve the nutritional goals of the family with their current resource endowment. This, of course, assumes that there is not tremendous production or price risk associated with field crop production. The scenarios suggest that achieving the basic RDAs for nutrition could be done by continuing to support the practice of planting the field crops. However, diversifying by growing more vegetable varieties in place of field crops also provides the farm family with the ability to meet its nutritional needs, but with a lower standard of living than if the farm family focuses on growing field crops. Again, if market or production volatility is high in the study area, it may be better to grow the food for on-farm consumption as a method to reduce nutritional risks faced by the family. This would be especially true if no off-farm labor opportunities exist.

The MyPlate scenarios suggest that the guidelines the developed world is attempting to employ to improve health through better eating choices are probably not well suited for a developing world situation. This suggests that modifying the “ideals” for dietary guidelines is appropriate in developing world situations. MyPlate is a feasible diet for this community; however, basing diets on MyPlate guidelines rather than RDAs could only be done by farm families accepting a greatly reduced standard of living.

The area of Cochas is a good place to conduct this type of an analysis. The area has an ideal climate to grow crops year around, fertile soils, and access to water. Some locations in other developing countries may not be as fortunate and the tradeoffs associated with growing vegetables rather than field crops would probably be different than what is presented here. Even in this ideal setting, the model continued to select spinach for purchase because the family could not grow a crop that satisfied nutrition in all periods. This would likely be a worse problem in locations that do not have a wide selection of garden varieties and that have a more limited crop calendar (e.g., weather does not permit year around production).

The results could support the need for intensive gardening methods to be taught to impoverished small-scale farmers if land is available and not all available family labor is being used. The results presented here may also further support the use of genetically modified seed varieties that can be grown/planted in earlier or later periods which would allow a farm family to better use idle land and family time. However, it also demonstrates that when off-farm employment is available that being self-sufficient still does not offer a higher standard of living to the farm family compared to if some off-farm income is generated.

While higher standards of living can be achieved by emphasizing cash crops and also working off the farm than by emphasizing growing vegetable crops for on-farm consumption, there may also be risks associated with this strategy. Observation within the community of Cochas seems to support the idea that a mixed strategy be implemented. This means that small-scale farmers will likely emphasize field crop production, but may also choose to have gardens plots as a method to spread risks to some degree. This is consistent with portfolio theory but also suggests that risk-reducing activities such as better infrastructure, irrigation systems, and fertilizer would tend to raise living standards in the study area.

CHAPTER 5

CONCLUSIONS

Within the global health debate a new focus has been placed on the important role played by agriculture in alleviating some of the suffering existing in the developing world. The objective of this study was to integrate economic, nutrition, and agronomic principles into a mathematical-programming, decision making framework which considers a broader range of resources and constraints for analysis. Based on primary data gathered in surveys, a representative small-scale rural poor family situation in northern Ecuador was simulated by a linear programming model. The LP assumed that the overall goal of the farm family was to maximize discretionary cash at the end of the year after satisfying all basic nutritional and economic family needs. We examined how the availability of family labor and hired, non-family labor affect the family's decisions. We also examined how the availability of off-farm employment affects the family's decision as to what to plant/produce on the farm. We also observed how different nutritional requirements for the farm family affect results (farm family decisions).

The model results demonstrated that a higher standard of living for the farm family is not necessarily reached with a more self-sufficient family farm. Farming as a primary source of income has failed to guarantee sufficient livelihoods for small-scale farm household in the study area, as evidenced by most adult male family members seeking employment off-farm as well as working on the farm. Past macro agricultural developmental policies employed by NGOs and GOs in this study area have largely produced little improvement in this part of Ecuador and diversification into off-farm activities has become the norm.

This study supports that notion that involvement in off-farm income-generating activities may lead to these farm families deciding to produce less on the farm due to the generally higher return to labor in off-farm employment than in on-farm farming activities. Although on-farm production may be reduced because of off-farm employment, the scenarios explored in this report conclude that able fathers should chose to work off-farm when the opportunity exists if they wish to increase their family's standard of living as measured by household income. This study also presents a scenario which indicates that returns to the farm family can be increased even more when the father works off the farm if the family hires replacement labor for the family's father.

In areas that have an established field crop practice, this model indicates that diversifying resources away from producing these cash crops is only justifiable if low opportunity costs exist for the family labor and if replacement food cannot be purchased for reasonable prices. A higher standard of living would be produced by focusing on the field crop production than focusing on small-scale garden crop varieties for on-farm consumption.

The results imply that when developing interventions that accounting for opportunity costs is tremendously important to consider when creating programs with the intention that these programs will be self-sustaining once donor funding ends. At the time of the survey, solutions to the development problems of the area were being sought with remarkable disregard for the constraints and opportunity costs, particularly those associated with farm family labor, faced by the farm families.

This thesis also dedicated considerable effort to develop an initial set of enterprise budgets for a representative small-scale farm in the study area. These budgets will hopefully help facilitate analyses undertaken by NGOs and GOs who are considering various interventions to assist farm families in the study area. A careful analysis of the estimated costs and returns associated with different interventions can aid agencies and donors in familiarizing themselves with potential inputs, input prices, yields, management practice, and expected income specific to the study area. These estimated costs and returns may also provide a basis for further in-depth study of the components contributing to farm estimated income including such things as actions affecting yields (e.g., fertilizer, rainfall, and species or varieties) and market prices (price risk, prices net of marketing costs, market information, and market infrastructure issues) when building models and conducting assessments of risks and other factors affecting outcomes for the farm family. The model developed for this study could benefit from additional information being incorporated about nutritional requirements of the rural poor, optional labor saving practices for on-farm activities, and the use of enhanced seed varieties.

The MyPlate scenarios raise the argument that nutritional programs developed to address the problems of overweight people in the developed world are not always applicable in the developing world. The nutritional constraint used in this model was composed of RDAs from the developed world. The daily rituals and labor practices observed in the study are not typical of the population for which the RDAs were devised. This model could benefit from a more applicable dietary constraint applicable to the study area. These periods could then be comprised of specific dietary needs for the nutrient levels demanded for the actual level of physical activity experienced by members of the farm family. This new dietary constraint would account for idle time as well as for nutritional needs during intense periods of planting and harvest which are typical of these small-scale farmers.

The model was limited in family labor placement to being employed on or off the farm. A more dynamic variable could be constructed that allowed selection of mechanized preparation of land and harvest activities with the associated costs and labor saving attributes. Other farm technologies that existed in this region of Ecuador but were not studied within this thesis were seed spreaders, harvesting machines, and other tractor implements. A better understanding of the efficiencies gained by using more mechanized cropping practice than considered in this study may produce a different selection of enterprises and farming practices that were considered here. It may also provide insight to whether or not the study area has a competitive advantage in the crops it grows due to low-cost labor (especially when accounting for opportunity cost).

In the data collection for the enterprise budgets, it was found that genetically-modified (GM) seed varieties were available for the types of field crops that this area grows but none were being used by farmers in Cochas. The community continues to practice saving seeds and was unaware of the possible benefits that GM seed strains might provide such as reducing the time a crop is in the ground, higher yields, or lower water requirements. If this model had incorporated the option to select modified (GM) varieties with their increased costs and benefits for either the field and/or garden crops, it is possible that better alternatives for the farm family than described in the scenarios considered could have been achieved. For example, these enhanced seed varieties may facilitate greater yields which would in effect achieve the same benefit as increasing the amount of land farmed by the family.

Some of the most important constraints faced by the rural small-scale farmer are land, labor, and nutrition. The means used to assist in creating a better standard of living for these rural poor while providing adequate nutrition may also vary across different cultures. An important concept that agricultural and economic programs should have at the forefront of the intervention planning process is that the intervention should be self-sustaining if possible. For aid programs to be sustainable, and thus truly effective, the programs need to take into account the specific circumstances that may be idiosyncratic to the locality in which are operating. Essentially, planned interventions also need to reflect the structure and functions of the local culture. Hopefully the model described in this study provides the means to begin to objectively evaluate an intervention program in an integrated, whole-farm decision-making framework.

“There is bad aid and there is good aid. The bad aid is that one which creates dependencies, but good aid is that which is targeted to create capacities in people so that they are able to live on their own activities,” Paul Kagame, The President of Rwanda (YouTube, 2007).

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APPENDICES

Appendix A

Table 13. Estimated Costs & Returns for One Hectare of Barley in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Barley[a]			Kg	760	$0.23	$174.80	87.40%
Seed[b]			Kg	140	$0.18	$25.20	12.60%
Total Revenue						$200.00	100.00
Operating Expenses							
Seed			Kg	140	$0.18	$25.20	12.60%
Tractor[c]			Hour	1.5	$20.00	$30.00	15.00%
Tools[d]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	3.75%
Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	3.33%
Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	2.00%
Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	3.75%
Oxen[e]			Hour	2.00	$2.50	$5.00	2.50%
Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.25%
Pesticide[g]			Hectare	1.00	$18.00	$18.00	9.00%
Interest[h]				$17.50	18%	$3.15	1.58%
Total Non-Labor Operating Expenses						$107.52	53.76%
Returns to Land, Labor & Management						$92.48	46.24%
Return Per Hour of Labor						$0.44	0.22%
Return Per Day of Labor						$3.56	1.78%
Labor							
Land Prep/Planting[i]			Hours	8.00	$0.63	$5.00	2.50%
Maintenance[j]			Hours	56.00	$0.63	$35.00	17.50%
Harvest[k]			Hours	144.00	$0.63	$90.00	45.00%
Total Labor Expense						$130.00	65.00%
Returns to Land & Management						$(37.52)	-18.76%

[a] Crop information gathered at hectare level. Average 900 kg per hectare (9 quintales).
[b] 140 kg of seed needed for sowing by hand. Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation and seed covering. Tractor hours not sold in partial units but can be used to prepare multiple plots.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation.
[e] Oxen lease rate varies from family to family. Is normally borrowed from neighbor and may be paid by trade for food.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Pesticide application done by 3rd party and includes labor.
[h] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[i] Includes supervisory work of tractor time and running the oxen team to cover seed.
[j] Barley averages 180 days with two hours per week maintenance.
[k] Five to seven days for 2-3 days. If land is flat enough, harvester is available for $40/hour and 2 hours needed for hectare.
* Farm gate price
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 14. Estimated Costs & Returns for One Square Meter of Beets in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Beets[a]			Kg	6.73	$0.30	$2.02	100%
Seed[b]			Gram	0	$0.04	$ --	0%
Total Revenue						$2.02	100%
Operating Expenses							
Seed			Gram	1.68	$0.04	$0.07	4%
Water			Days	100.00	$0.001	$0.10	5%
Tools[c]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[d]	1	5	price/yr/ha	1	$0.03	$0.03	2%
Repairs[e]			per mt^2	1	$0.02	$0.02	1%
Garden Enclosure[f]		5	meters/area/yr	0.06	$2.10	$0.13**	6%
Interest				$0.19	18%	$0.03	2%
Total Non-Labor Operating Expenses						$0.39	19%
Returns to Land, Labor & Management						$1.63	81%
Return Per Hour of Labor						$0.08	4%
Return Per Day of Labor						$0.68	33%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	51%
Maintenance			Hours	5.89	$0.63	$3.68	182%
Harvest			Hours	0.25	$0.63	$0.16	8%
Total Labor Expense						$4.87	241%
Returns to Land & Management						$(3.24)	-160%

[a] Beet yield measured per 33cm^2 producing 1.333 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 15. Estimated Costs & Returns for One Square Meter of Broccoli in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Broccoli			Kg	3.69	$0.25	$0.92	100%
Seed			Gram	0	$0.06	$ --	0%
Total Revenue						$0.92	100%
Operating Expenses							
Seed			Gram	0.17	$0.06	$0.01	1%
Water			Days	60.00	$0.001	$0.06	7%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	3%
Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	14%
Interest				$0.09	18%	$0.02	2%
Total Non-Labor Operating Expenses						$0.27	29%
Returns to Land, Labor & Management						$(0.66)	71%
Return Per Hour of Labor						$(0.04)	4%
Return Per Day of Labor						$(0.31)	34%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	112%
Maintenance			Hours	3.54	$0.63	$2.21	240%
Harvest			Hours	0.25	$0.63	$0.16	17%
Total Labor Expense						$3.40	369%
Returns to Land & Management						$(2.74)	-297%

[a] Broccoli yield measured per $33cm^2$ producing 0.73 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or $200m^2$.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area $4.8m^2$.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 16. Estimated Costs & Returns for One Square Meter of Carrots in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Carrots[a]			Kg	5.23	$0.38*	$1.96	100%
Seed[b]			Gram	0	$0.04	-----	0%
Total Revenue						$1.96	100%
Operating Expenses							
Seed			Gram	0.45	$0.04	$0.02	1%
Water[c]			Days	110.00	$0.001	$0.11	6%
Tools[d]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[e]	1	5	price/yr/ha	0.00002	$1565.00	$0.03	2%
Repairs[f]			per mt^2	1	$0.02	$0.02	1%
Garden Enclosure[g]		5	meters/area/yr	0.06	$2.10	$0.13**	6%
Interest[h]				$0.15	18%	$0.03	1%
Total Non-Labor Operating Expenses						$0.33	17%
Returns to Land, Labor & Management						$1.63	83%
Return Per Hour of Labor						$0.19	10%
Return Per Day of Labor						$1.55	79%
Labor							
Land Prep/Planting[i]			Hours	1.65	$0.63	$1.03	53%
Maintenance[j]			Hours	6.48	$0.63	$4.05	207%
Harvest[k]			Hours	0.25	$0.63	$0.16	8%
Total Labor Expense						$5.24	267%
Returns to Land & Management						$(3.61)	-184%

[a] Carrot yield measured per 33cm^2 producing 1.035 kg without leaves initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Water tariff is $0.21 per m^3. Watering twice daily incurring $0.03 cost per month per square meter of crop.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters, or 200m^2 .
[f] Repairs begin year 2 at $4 through year 5 for 200m^2.
[g] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend of geography and size of plot.
[h] Interest calculated on direct expenses, (i.e. seed, water, drip system repair) and charged for time crop in ground.
[i] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area of 4.8 m^2 .
[j] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding and maintaining.
[k] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping within 12 calendar months.
Garden crop planted in rows 60cm on center with a 33cm bed width.

Table 17. Estimated Costs & Returns for One Square Meter of Cauliflower in Cochas,Ecuador

				Unit	Quantity	Price	Amount	
Revenue								
Cauliflower				Kg	6.16	$0.18	$1.08	100%
Seed				Gram	0	$0.08	$ --	0%
Total Revenue							$1.08	100%
Operating Expenses								
Seed				Gram	0.17	$0.08	$0.01	1%
Water				Days	60.00	$0.001	$0.06	6%
Tools[a]		# / Hectare	Life (Yrs.)					
	Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
	Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
	Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
	Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]		1	5	price/yr/ha	1	$0.03	$0.03	3%
	Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]			5	meters/area/yr	0.06	$2.10	$0.13**	12%
Interest					$0.09	18%	$0.02	2%
Total Non-Labor Operating Expenses							$0.27	25%
Returns to Land, Labor & Management							$0.81	75%
Return Per Hour of Labor							$0.05	4%
Return Per Day of Labor							$0.38	35%
Labor								
	Land Prep/Planting			Hours	1.65	$0.63	$1.03	96%
	Maintenance			Hours	3.54	$0.63	$2.21	205%
	Harvest			Hours	0.25	$0.63	$0.16	14%
Total Labor Expense							$3.40	315%
Returns to Land & Management							$(2.59)	-240%

[a] Cauliflower yield measured per 33cm^2 producing 1.220 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 18. Estimated Costs & Returns for One Square Meter of Celery in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Celery			Kg	4.69	$0.25	$1.17	100%
Seed			Gram	0	$0.13	$ --	0%
Total Revenue						$1.17	100%
Operating Expenses							
Seed			Kg	0.22	$0.13	$0.03	3%
Water			Days	90.00	$0.00	$0.09	8%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	3%
Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	11%
Interest				$0.14	18%	$0.03	2%
Total Non-Labor Operating Expenses						$0.32	28%
Returns to Land, Labor & Management						$0.85	72%
Return Per Hour of Labor						$0.05	4%
Return Per Day of Labor						$0.36	31%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	88%
Maintenance			Hours	5.30	$0.63	$3.31	283%
Harvest			Hours	0.25	$0.63	$0.16	13%
Total Labor Expense						$4.50	384%
Returns to Land & Management						$(3.65)	-311%

[a] Celery yield measured per $33cm^2$ producing 0.929 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or $200m^2$.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area $4.8m^2$.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 19. Estimated Costs & Returns for One Square Meter of Chard in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Chard			Kg	5.05	$0.13	$0.63	100%
Seed			Gram	0	$0.04	$ --	0%
Total Revenue						$0.63	100%
Operating Expenses							
Seed			Gram	1.68	$0.04	$0.06	9%
Water			Days	150.00	$0.001	$0.15	24%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	5%
Repairs[c]			per mt^2	1	$0.02	$0.02	3%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	20%
Interest				$0.23	18%	$0.04	7%
Total Non-Labor Operating Expenses						$0.43	68%
Returns to Land, Labor & Management						$0.20	32%
Return Per Hour of Labor						$0.01	1%
Return Per Day of Labor						$0.07	11%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	163%
Maintenance			Hours	8.84	$0.63	$5.52	875%
Harvest			Hours	0.25	$0.63	$0.16	25%
Total Labor Expense						$6.71	1063%
Returns to Land & Management						$(6.51)	-1031%

[a] Chard yield measured per 33cm^2 producing 1 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 20. Estimated Costs & Returns for One Hectare of Chocho in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Chocho[a]			Kg	770	$0.30	$231.00	97.72%
Seed[b]			Kg	30	$0.18	$5.40	2.28%
Total Revenue						$236.40	100.%
Operating Expenses							
Seed			Kg	30	$0.18	$5.40	2.28%
Tractor[c]			Days	2	$20.00	$40.00	16.92%
Tools[d]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	3.17%
Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	2.82%
Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	1.69%
Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	3.17%
Oxen[e]			Hour	3.00	$2.50	$7.50	3.17%
Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.21%
Interest[g]				$23.33	18%	$4.20	1.78%
Total Non-Labor Operating Expenses						$83.27	35.22%
Returns to Land, Labor & Management						$153.13	64.78%
Return Per Hour of Labor						$1.99	0.84%
Return Per Day of Labor						$15.91	6.73%
Labor[h]							
Land Prep/Planting			Hours	8.00	$0.63	$5.00	2.12%
Maintenance			Hours	24.00	$0.63	$15.00	6.35%
Harvest			Hours		$0.63	$28.13	11.90%
Total Labor Expense						$43.13	18.24%
Returns to Land & Management						$110.01	46.53%

[a] Crop information gathered for 1700 m^2 and scaled to hectare. Average 800 kg.
[b] Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation and seeding.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team used to cover seed behind tractor.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[h] Labor hours collected for 1700 m^2, and then scaled to hectare.
[i] One to two workers for two days.
[j] Mostly weeding.
[k] Will need five to seven workers to clear field in a day.
*Farm gate price.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 21. Estimated Costs & Returns for One Hectare of Maize in Cochas, Ecuador

				Unit	Quantity	Price	Amount	
Revenue								
Corn[a]				Kg	3008	$0.33	$992.54	98.96%
Seed[b]				Kg	69	$0.15	$10.38	1.04%
Total Revenue							$1,002.92	100 %
Operating Expenses								
Seed				Kg	69	$0.15	$10.38	1.04%
Tractor[c]				Hour	1.65	$20.00	$33.08	3.30%
Tools[d]		# / Hectare	Life (Yrs.)					
	Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	0.75%
	Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	0.66%
	Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	0.40%
	Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	0.75%
Oxen[e]				Hour	2.00	$2.50	$5.00	0.50%
	Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.05%
Interest[g]					$11.03	18%	$1.98	0.20%
Total Non-Labor Operating Expenses							$76.61	7.64%
Returns to Land, Labor & Management							$926.31	92.36%
Return Per Hour of Labor							$1.67	0.17%
Return Per Day of Labor							$13.38	1.33%
Labor[h]								
	Land Prep/Planting[i]			Hours	123.08	$0.63	$76.92	7.67%
	Maintenance[j]			Hours	246.15	$0.63	$153.85	15.34%
	Harvest[k]			Hours	184.62	$0.63	$115.38	11.50%
Total Labor Expense							$346.15	34.51%
Returns to Land & Management							$580.16	57.85%

[a] Crop information gathered for 2600 m^2 and scaled to hectare. Average 800 kg with max being about (20) 100 kg sacks (8-20 quintals).
[b] 40 lbs of seed needed for sowing by hand. Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation. Tractor hours not sold in partial units but can be used to prepare multiple plots.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team used to cover seed behind tractor.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[h] Labor hours collected for 2600 m^2, and then scaled to hectare
[i] Need two worker for two full days to finish land preparation and plant crop. Data scaled up to quantity needed for hectare.
[j] Includes weeding and covering roots that become exposed. Average four hours per week that crop is in ground.
[k] Need workers for two days for harvest. Some portion of crop may be left in field for storage and harvested for meals when needed.
* Farm gate price
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 22. Estimated Costs & Returns for One Square Meter of Green Cabbage in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Green Cabbage			Kg	5.97	$0.21	$1.22	100%
Seed			Gram	0	$ 0.05	$ --	0%
Total Revenue						$1.22	100%
Operating Expenses							
Seed			Gram	0.17	$0.05	$0.01	1%
Water			Days	100.00	$0.001	$0.10	8%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	3%
Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	10%
Interest				$0.13	18%	$0.02	2%
Total Non-Labor Operating Expenses						$0.31	25%
Returns to Land, Labor & Management						$0.91	75%
Return Per Hour of Labor						$0.05	4%
Return Per Day of Labor						$0.38	31%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	84%
Maintenance			Hours	5.89	$0.63	$3.68	301%
Harvest			Hours	0.25	$0.63	$0.16	13%
Total Labor Expense						$4.87	398%
Returns to Land & Management						$(3.96)	-328%

[a] Green cabbage yield measured per 33cm^2 producing 1.182 kg without leaves.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 23. Estimated Costs & Returns for One Square Meter of Green Onion in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Onion[a]			Kg	1.35	$0.26	$0.35	100%
Seed[b]			Gram	0	$0.11	$ --	0%
Total Revenue						$0.35	100%
Operating Expenses							
Seed			Gram	0.45	$0.11	$0.05	14%
Water			Days	100.00	$0.001	$0.10	28%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	9%
Repairs[c]			per mt^2	1	$0.02	$0.02	6%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	36%
Interest				$0.17	18%	$0.03	9%
Total Non-Labor Operating Expenses						$0.36	102%
Returns to Land, Labor & Management						$(0.01)	-2%
Return Per Hour of Labor						$(0.00)	0%
Return Per Day of Labor						$(0.00)	-1%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	293%
Maintenance			Hours	5.89	$0.63	$3.68	1047%
Harvest			Hours	0.25	$0.63	$0.16	44%
Total Labor Expense						$4.87	1384%
Returns to Land & Management						$(4.88)	-1386%

[a] Green onion yield measured per 33cm^2 producing 0.268 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 24. Estimated Costs & Returns for One Square Meter of Lettuce in Cochas, Ecuador

	# / Hectare	Life (Yrs.)	Unit	Quantity	Price	Amount	
Revenue							
Lettuce			Kg	3.05	$0.20	$0.61	100%
Seed			Gram	0	$0.07	$ --	0%
Total Revenue						$0.61	100%
Operating Expenses							
Seed			Gram	0.34	$0.07	$0.02	4%
Water			Days	90.00	$0.001	$0.09	15%
Tools[a]							
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	5%
Repairs[c]			per mt^2	1	$0.02	$0.02	3%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	21%
Interest				$0.13	18%	$0.02	4%
Total Non-Labor Operating Expenses						$0.32	52%
Returns to Land, Labor & Management						$0.29	48%
Return Per Hour of Labor						$0.02	3%
Return Per Day of Labor						$0.12	20%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	169%
Maintenance			Hours	5.30	$0.63	$3.31	544%
Harvest			Hours	0.25	$0.63	$0.16	26%
Total Labor Expense						$4.50	739%
Returns to Land & Management						$(4.21)	-691%

[a] Lettuce yield measured per 33cm^2 producing 0.603 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 25. Estimated Costs & Returns for One Hectare of Oats in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Oats[a]			Kg	800	$0.25	$200.00	88.11%
Seed[b]			Kg	150	$0.18	$27.00	11.89%
Total Revenue						$227.00	100%
Operating Expenses							
Seed			Kg	150	$0.18	$27.00	11.89%
Tractor[c]			Hour	1.5	$20.00	$30.00	13.22%
Tools[d]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	3.30%
Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	2.94%
Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	1.76%
Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	3.30%
Oxen[e]			Hour	3.00	$2.50	$7.50	3.30%
Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.22%
Interest[g]				$10.00	18%	$1.80	0.79%
Total Non-Labor Operating Expenses						$92.47	40.73%
Returns to Land, Labor & Management						$134.53	59.27%
Return Per Hour of Labor						$0.48	0.21%
Return Per Day of Labor						$3.84	1.69%
Labor							
Land Prep/Planting[h]			Hours	8.00	$0.63	$5.00	2.20%
Maintenance[i]			Hours	104.00	$0.63	$65.00	28.63%
Harvest[j]			Hours	168.00	$0.63	$105.00	46.26%
Total Labor Expense						$175.00	77.09%
Returns to Land & Management						$(40.47)	-17.83%

[a] Average between 900 to 1000 kg.
[b] Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation and seeding.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team used to help evenly spread seed and cover seed behind tractor.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[h] Includes supervisory work and running oxen team.
[i] Mostly weeding, average four hours per week.
[j] Will need five to seven workers for two to three days to clear, or harvester runs $40/hour and takes 2 hours per hectare.
*Farm gate price.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 26. Estimated Costs & Returns for One Hectare of Potatoes in Cochas, Ecuador

				Unit	Quantity	Price	Amount	
Revenue								
Potato[a]				Kg	8000	$0.35	$2,800	87.04%
Seed[b]				Kg	1000	$0.42	$417	12.96%
Total Revenue							$3,217.00	100%
Operating Expenses								
Seed				Kg	1000	$0.42	$417.00	12.96%
Tractor[c]				Hour	10	$25.00	$250.00	7.77%
Tools[d]		# / Hectare	Life (Yrs.)					
	Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	0.23%
	Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	0.21%
	Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	0.12%
	Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	0.23%
Oxen[e]				Hour	20.00	$2.50	$50.00	1.55%
	Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.02%
Interest[g]					$145.83	18%	$26.25	0.82%
Total Non-Labor Operating Expenses							$769.42	23.92%
Returns to Land, Labor & Management							$2,447.58	76.08%
Return Per Hour of Labor							$1.25	0.04%
Return Per Day of Labor							$9.99	0.31%
Labor[h]								
	Land Prep/Planting[i]			Hours	1200.00	$0.625	$750.00	23.31%
	Maintenance[j]			Hours	280.00	$0.625	$175.00	5.44%
	Harvest[k]			Hours	480.00	$0.625	$300.00	9.33%
Total Labor Expense							$1,225.00	38.08%
Returns to Land & Management							$1,222.58	38.00%

[a] Crop information gathered for 1000 m^2 and scaled to hectare. Average 900 kg.
[b] Seed potatoes needed for sowing by hand. Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation. Plot plowed multiple times for soil preparation
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team utilized in addition to tractor to continue plowing/disking to break up soil.
[f] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[g] Labor hours collected for 1000 m^2, and then scaled to hectare.
[h] Five workers for three full days to finish land preparation and plant crop. Majority of time spent in cutting/planting potatoes.
[i] Mostly weeding.
[j] Will need five to seven workers to clear a field in a day.
* Farm gate price
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 27. Estimated Costs & Returns for One Hectare of Quinoa in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Quinoa[a]			Kg	782	$0.88	$688.16	96.22%
Seed[b]			Kg	18	$1.50	$27.00	3.78%
Total Revenue						$715.16	100%
Operating Expenses							
Seed			Kg	18	$1.50	$27.00	3.78%
Tractor[c]			Hour	6	$20.00	$120.00	16.78%
Tools[d]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	1.05%
Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	0.93%
Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	0.56%
Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	1.05%
Oxen[e]			Hour	2.00	$2.50	$5.00	0.70%
Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.07%
Interest[g]				$70.00	18%	$12.60	1.76%
Total Non-Labor Operating Expenses						$190.77	26.67%
Returns to Land, Labor & Management						$524.39	73.33%
Return Per Hour of Labor						$3.86	0.54%
Return Per Day of Labor						$30.85	4.31%
Labor							
Land Prep/Planting[h]			Hours	16	$0.63	$10.00	1.40%
Maintenance[i]			Hours	40	$0.63	$25.00	3.50%
Harvest[j]			Hours	80	$0.63	$50.00	6.99%
Total Labor Expense						$85.00	11.89%
Returns to Land & Management						$439.39	61.44%

[a] Average 800 kg.
[b] Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team used to cover seed behind tractor.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[h] Two people for an entire day to prep and plant.
[i] Supervising tractor, creating rows, covering seed.
[j] Mostly weeding, average two hours per week.
[k] Will need five workers for two days to clear field in a day.
*Farm gate price.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 28. Estimated Costs & Returns for One Square Meter of Radish in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Radish			Kg	0.77	$1.04	$0.80	100%
Seed			Gram	0	$0.03	$ --	0%
Total Revenue						$0.80	100%
Operating Expenses							
Seed			Gram	2.24	$0.03	$0.06	8%
Water			Days	30.00	$0.001	$0.03	4%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	4%
Repairs[c]			per mt^2	1	$0.02	$0.02	3%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	16%
Interest				$0.11	18%	$0.02	3%
Total Non-Labor Operating Expenses						$0.29	37%
Returns to Land, Labor & Management						$0.50	63%
Return Per Hour of Labor						$0.03	4%
Return Per Day of Labor						$0.27	33%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	129%
Maintenance			Hours	1.77	$0.63	$1.10	138%
Harvest			Hours	0.25	$0.63	$0.16	20%
Total Labor Expense						$2.29	287%
Returns to Land & Management						$(1.79)	-224%

[a] Radish yield measured per $33cm^2$ producing 0.152 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or $200m^2$.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area $4.8m^2$.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 29. Estimated Costs & Returns for One Square Meter of Red Cabbage in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Red Cabbage			Kg	6.17	$0.20	$1.26	100%
Seed			Gram	0	$0.05	$ --	0%
Total Revenue						$1.26	100%
Operating Expenses							
Seed			Gram	0.17	$0.05	$0.01	1%
Water			Days	100.00	$0.001	$0.10	8%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	2%
Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	10%
Interest				$0.13	18%	$0.02	2%
Total Non-Labor Operating Expenses						$0.31	25%
Returns to Land, Labor & Management						$0.95	75%
Return Per Hour of Labor						$0.05	4%
Return Per Day of Labor						$0.39	31%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	82%
Maintenance			Hours	5.89	$0.63	$3.68	292%
Harvest			Hours	0.25	$0.63	$0.16	12%
Total Labor Expense						$4.87	386%
Returns to Land & Management						$(3.92)	-310%

[a] Red cabbage yield measured per 33cm^2 producing 1.221 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 30. Estimated Costs & Returns for One Square Meter of Spinach in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Spinach			Kg	3.94	$0.09	$0.35	100%
Seed			Gram	0	$0.04	$ --	0%
Total Revenue						$0.35	100%
Operating Expenses							
Seed			Gram	1.68	$0.04	$0.06	778%
Water			Days	90.00	$0.001	$0.09	25%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	9%
Repairs[c]			per mt^2	1	$0.02	$0.02	6%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	36%
Interest				$0.17	18%	$0.03	9%
Total Non-Labor Operating Expenses						$0.36	101%
Returns to Land, Labor & Management						$(0.01)	-1%
Return Per Hour of Labor						$(0.00)	0%
Return Per Day of Labor						$(0.00)	-1%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	291%
Maintenance			Hours	5.30	$0.63	$3.31	935%
Harvest			Hours	0.25	$0.63	$0.16	44%
Total Labor Expense						$4.50	1270%
Returns to Land & Management						$(4.51)	-1271%

[a] Spinach yield measured per $33cm^2$ producing 0.780 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or $200m^2$.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area $4.8m^2$.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 31. Estimated Costs & Returns for One Square Meter of Tomato in Cochas, Ecuador

				Unit	Quantity	Price	Amount	
Revenue								
Tomato				Kg	4.84	$0.38	$1.81	100%
Seed				Gram	0	$0.16	$ --	0%
Total Revenue							$1.81	100%
Operating Expenses								
Seed				Gram	0.11	$0.16	$0.02	1%
Water				Days	120.00	$0.001	$0.12	7%
Tools[a]		# / Hectare	Life (Yrs.)					
	Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
	Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
	Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
	Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]		1	5	price/yr/ha	1	$0.03	$0.03	2%
	Repairs[c]			per mt^2	1	$0.02	$0.02	1%
Garden Enclosure[d]			5	meters/area/yr	0.06	$2.10	$0.13**	7%
Interest					$0.16	18%	$0.03	2%
Total Non-Labor Operating Expenses							$0.35	19%
Returns to Land, Labor & Management							$1.47	81%
Return Per Hour of Labor							$0.07	4%
Return Per Day of Labor							$0.57	32%
Labor								
	Land Prep/Planting			Hours	1.65	$0.63	$1.03	57%
	Maintenance			Hours	7.07	$0.63	$4.42	244%
	Harvest			Hours	0.25	$0.63	$0.16	9%
Total Labor Expense							$5.61	309%
Returns to Land & Management							$(4.14)	-228%

[a] Tomato yield measured per 33cm^2 producing 0.958 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 32. Estimated Costs & Returns for One Square Meter of Chinese Turnip in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Turnip			Kg	2.91	$0.35	$1.02	100%
Seed			Gram	0	$0.04	$ --	0%
Total Revenue						$1.02	100%
Operating Expenses							
Seed			Gram	0.22	$0.04	$0.01	1%
Water			Days	90.00	$0.001	$0.09	9%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	3%
Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	12%
Interest				$0.12	18%	$0.02	2%
Total Non-Labor Operating Expenses						$0.30	29%
Returns to Land, Labor & Management						$0.72	71%
Return Per Hour of Labor						$0.04	4%
Return Per Day of Labor						$0.31	30%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	101%
Maintenance			Hours	5.30	$0.63	$3.31	326%
Harvest			Hours	0.25	$0.63	$0.16	15%
Total Labor Expense						$4.50	442%
Returns to Land & Management						$(3.78)	-372%

[a] Turnip yield measured per 33cm^2 producing 0.576 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 33. Estimated Costs & Returns for One Hectare of Wheat in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Wheat[a]			Kg	4050	$0.16	$647.94	98.04%
Seed[b]			Kg	68	$0.19	$12.95	1.96%
Total Revenue						$660.89	100%
Operating Expenses							
Seed			Kg	68.00	$0.19	$12.95	1.96%
Tractor[c]			Hour	1.5	$20.00	$30.00	4.54%
Tools[d]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	1.50	$5.00	$7.50	1.13%
Rake	4	3	#/yr/m^2	1.33	$5.00	$6.67	1.01%
Hoe	4	5	#/yr/m^2	0.80	$5.00	$4.00	0.61%
Shovel	2	8	#/yr/m^2	0.25	$30.00	$7.50	1.13%
Oxen[e]			Hour	2.00	$2.50	$5.00	0.76%
Feed[f]			Flat Rate	1.00	$0.50	$0.50	0.08%
Interest[g]				$17.50	18%	$3.15	0.48%
Total Non-Labor Operating Expenses						$77.26	11.69%
Returns to Land, Labor & Management						$583.63	88.31%
Return Per Hour of Labor						$6.55	0.99%
Return Per Day of Labor						$52.38	7.93%
Labor[h]							
Land Prep/Planting[i]			Hours	16	$5.00	$80.00	12.10%
Maintenance[j]			Hours	17	$0.63	$10.71	1.62%
Harvest[k]			Hours	56	$5.00	$280.00	42.37%
Total Labor Expense						$370.71	56.09%
Returns to Land & Management						$212.91	32.22%

[a] Crop information gathered for 1700 m^2 and scaled to hectare. Average 800 kg.
[b] Seed quantity deducted from yield and saved for next crop.
[c] Tractor utilized in preparation and seeding.
[d] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[e] Oxen team used to cover seed behind tractor.
[f] Unconditional of time spent on farm, meals are provided by lease, calculated at 0.50 daily rate.
[g] Fee charged by 3rd party for tractor time financed through local bank at annual rate and calculated for time crop is in ground.
[h] Labor hours collected for 1700 m^2, and then scaled to hectare.
[i] One to two workers for two days.
[j] Mostly weeding.
[k] Will need five to seven workers to clear field in a day.
*Farm gate price.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months.

Table 34. Estimated Costs & Returns for One Square Meter of White Onion in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Onion			Kg	3.35	$0.26	$0.87	100 %
Seed			Gram	0	$0.07	$ --	0%
Total Revenue						$0.87	100%
Operating Expenses							
Seed			Gram	0.45	$0.07	$0.03	4%
Water			Days	120.00	$0.001	$0.12	14%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	4%
Repairs[c]			per mt^2	1	$0.02	$0.02	2%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	14%
Interest				$0.17	18%	$0.03	4%
Total Non-Labor Operating Expenses						$0.36	42%
Returns to Land, Labor & Management						$0.51	58%
Return Per Hour of Labor						$0.02	3%
Return Per Day of Labor						$0.20	23%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	118%
Maintenance			Hours	7.07	$0.63	$4.42	507%
Harvest			Hours	0.25	$0.63	$0.16	18%
Total Labor Expense						$5.61	643%
Returns to Land & Management						$(5.10)	-585%

[a] Onion yield measured per 33cm^2 producing 0.664 kg initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or 200m^2.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area 4.8m^2.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 35. Estimated Costs & Returns for One Square Meter of Zucchini in Cochas, Ecuador

			Unit	Quantity	Price	Amount	
Revenue							
Zucchini			Kg	1.94	$0.18	$0.34	100%
Seed			Gram	0	$0.16	$ --	0%
Total Revenue						$0.34	100%
Operating Expenses							
Seed			Gram	0.67	$0.16	$0.11	31%
Water			Days	75.00	$0.001	$0.08	22%
Tools[a]	# / Hectare	Life (Yrs.)					
Machete	3	2	#/yr/m^2	0.00015	$5.00	$0.00075	0%
Rake	4	3	#/yr/m^2	0.00013	$5.00	$0.00067	0%
Hoe	4	5	#/yr/m^2	0.00008	$5.00	$0.00040	0%
Shovel	2	8	#/yr/m^2	0.00003	$30.00	$0.00075	0%
Drip System[b]	1	5	price/yr/ha	1	$0.03	$0.03	9%
Repairs[c]			per mt^2	1	$0.02	$0.02	6%
Garden Enclosure[d]		5	meters/area/yr	0.06	$2.10	$0.13**	37%
Interest				$0.20	18%	$0.04	11%
Total Non-Labor Operating Expenses						$0.40	117%
Returns to Land, Labor & Management						$(0.06)	-17%
Return Per Hour of Labor						$(0.00)	-1%
Return Per Day of Labor						$(0.03)	-8%
Labor							
Land Prep/Planting			Hours	1.65	$0.63	$1.03	304%
Maintenance			Hours	4.42	$0.63	$2.76	814%
Harvest			Hours	0.25	$0.63	$0.16	46%
Total Labor Expense						$3.95	1164%
Returns to Land & Management						$(4.01)	-1181%

[a] Zucchini yield measured per $33cm^2$ producing 2.304 kg with 6 week harvest initially.
[b] Assume no saving of seed and purchasing seed each season.
[c] Number of tools utilized on full hectare divided by useful life to calculate per year straight line depreciation, then divided by 10,000 to arrive at quantity used per year per m^2.
[d] Drip irrigation kit for hectare is $65 for valves/diverters, $1500 for tubing. Five year depreciation. Same style of kit is $43 for garden crop area of 20x10 meters or $200m^2$.
[e] Repairs begin year 2 at $4 through year 5 for 200 m^2. Scaled to hectare.
[f] Most efficient garden plan assumed utilizing minimal square area. Netting not used for small gardens. Utilization of wind break and security netting at larger scale will depend on geography and size of plot.
[g] Interest calculated on direct expenses, i.e. seed, water, drip system repair.
[h] Worker can prepare and plant a row that has 33cm bed, spaced 60cm on center, and 8m long; total area $4.8m^2$.
[i] Maintenance needed calculated by water days divided by 7 for weeks. Each row requires 4 hours every other week for weeding/maintaining.
[j] Harvest as crop becomes ripe. Common practice to leave crop in field for storage until needed.
*Garden variety crop value derived using half of market price.
**Garden enclosure amount should be calculated by linear meters needed divided by area encompassed and then divided by useful life which is multiplied by netting price per linear meter.
Note: Final revenue and expenses should assume a minimum of double cropping with 12 calendar months. Garden crop planted in rows 60cm on center with a 33cm wide bed.

Table 36. Estimated Costs & Returns for Small Poultry Flock in Cochas, Ecuador

		Unit	Quantity	Price	Amount	
Revenue						
Eggs[a]		Egg	2044	$0.07	$143.08	71.87%
Salvage Price[b]		Chicken	7	$8.00	$56.00	28.13%
Total Revenue					$199.08	100%
Operating Expenses						
Chicken[c]		Hens	7	$8.00	$56.00	28.13%
Feed[d]		Days	365	$0.01	$3.65	1.83%
Water[e]		0.001 m^3	2555	$0.0002	$0.54	0.27%
	Life (Yrs.)					
Enclosure[f]	7	#/yr	0.14	$30.00	$4.29	2.15%
Interest[g]			$56.00	18%	$10.08	5.06%
Total Non-Labor Operating Expenses					$74.55	37.45%
Returns to Land, Labor & Management					$124.53	62.55%
Return Per Hour of Labor					$1.36	0.69%
Return Per Day of Labor					$10.92	5.48%
Labor[h]						
Feeding/Watering		Hours	29.2	$0.63	$18.40	9.24%
Penning		Hours	62.05	$0.63	$39.09	19.64%
Total Labor Expense					$57.49	28.88%
Returns to Land & Management					$67.04	33.68%

[a] Average production is 0.8 eggs per day per hen. Seven hens is average flock
[b] Market price for egg producing hen is $8
[c] Average flock size is seven hens
[d] Feed is typically comprised of grains harvested at no cost and supplemented with production feed production feed rate of $0.04 per day per hen scaled to 25% to account for supplemental use
[e] 0.001 m^3 per day per hen summed for 365 days and seven hens
[f] Coop capacity is about 10 hens and useful life is seven years
[g] Interest rate of 18% annual charged on purchase price of hens and accumulated for year
[h] 10 minutes per day for feeding. 20 minutes per day gathering into coop labor rate of $5 per eight hour day, $0.625 per hour

Table 37. Estimated Costs & Returns for a Heifer During 13 Months in Cochas, Ecuador

		Unit	Quantity	Price	Amount	
Revenue						
Milk[a]		Liter	900	$0.20	$180.00	36.86%
Salvage Price[b]		Cow	0.22	$500.00	$108.33	22.18%
		Calf	1	$200.00	$200.00	40.96%
Total Revenue					$488.33	100%
Operating Expenses						
Feed[c]		Day	390	$ --	$ --	0.00%
Water[d]		$0.075m^3$	390	$0.02	$6.16	1.26%
Veterinary[e]		Visit	3	$15.00	$45.00	9.22%
	Life (Yrs.)					
Cow[f]	5	#/yr	0.22	$300.00	$65.00	13.31%
Interest[g]			$12.68	18%	$11.41	2.34%
Total Non-Labor Operating Expenses					$127.57	26.12%
Returns to Land, Labor & Management					$360.76	73.88%
Return Per Hour of Labor					$2.78	0.57%
Return Per Day of Labor					$22.20	4.55%
Labor[h]						
Feeding/Watering		Hours	65.00	$0.63	$40.95	8.39%
Penning, Moving Tether		Hours	65.00	$0.63	$40.95	8.39%
Lactating		Hours	65.00	$0.63	$40.95	8.39%
Total Labor Expense					$122.85	25.16%
Returns to Land & Management					$237.91	48.72%

[a] Average three liters a day milking for 300 days. Farm gate price of $0.20/litter

[b] Final value at five years dispersed over 60 months evenly and summed for 13 month period

[c] Feed is typically provided by crop remnants and forage on
hill sides

[d] 20 gallons a day for lactating cow = 0.0757 cubic meters at an expense of $0.21 per m3

[e] Average three visits a year at an expense of $15 per visit

[f] Assuming bred heifer calving once a year and kept for five years

[g] Interest rate of 18% annual summed for 13 month expense

[h] Average half hour per day spent feeding, moving tether, and milking, assumed labor rate is $5 per day for eight hours, $0.625 per hour

Table 38. Estimated Costs & Returns for Guinea Pig in Cochas, Ecuador

	Life (Yrs.)	Unit	Quantity	Price	Amount	
Revenue						
Salvage Price		Pig[a]	2	$7.00	$14.00	22.58%
Pup		Pup[b]	12	$4.00	$48.00	77.42%
Total Revenue					$62.00	100%
Operating Expenses						
Guinea Pig		Pig	2	$7.00	$14.00	22.58%
Feed[c]		Day	365	$ --	$ --	0.00%
Water[d]		0.00008 m^3	1402	$0.00002	$0.024	0.04%
Enclosure[e]	5	#/yr	0.1428571	$20.00	$2.86	4.61%
Interest[f]			$14.00	18%	$2.52	4.06%
Total Non-Labor Operating Expenses					$19.40	31.29%
Returns to Land, Labor & Management					$42.60	68.71%
Return Per Hour of Labor					$0.70	1.13%
Return Per Day of Labor					$5.60	9.04%
Labor[g]						
Feeding/Watering		Hours	60.83	$0.63	$38.33	61.81%
Total Labor Expense					$38.33	61.81%
Returns to Land & Management					$4.27	6.89%

[a] Purchase male and female to begin. Typical practice is to have 10 females to every male

[b] Average litter size is three pups and five gestations per year at 67 days morbidity rate is 20%. Assume survival for 12 of the 15 pups ready for market at eight weeks

[c] Typical practice suggests feed being grass, grains, vetch, and garden waste with no cost if feed is purchased, averages to $0.04 per day per pig

[d] 80 cc per day per adult pig. Adult pig water expense calculated for year. Water expense calculated for 12 pups for eight weeks

[e] Enclosure capacity is about 30 pigs

[f] Calculated on purchase price of pigs for year

[g] Labor calculated at 10 minutes per day for feeding labor rate is $5 per eight hour day. 62.5 cents per hour

Note: Guinea Pig production practices confirmed with Paul Johnston (Johnston, 2012)

Appendix B

Table 39. Summary of Practiced Planting and Harvest Schedule for Field and Vegetable Crops in Cochas, Ecuador

Crop Name	Planting	Months of Year																							
		January		February		March		April		May		June		July		August		September		October		November		December	
Corn	1st					1	1	2	2	2	2	2	2	3	3										
	2nd	2	2	2	2	3	3																		1
Barley	1st		1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3							
	2nd	2	2	2	2	2	2	2	3													1	2	2	2
Potato	1st						1	1	2	2	2	2	2	2	2	2	2	2	2	3	3				
	2nd	3										1	1	2	2	2	2	2	2	2	2	2	2	2	3
	3rd	2	2	2	2	2	2	3	3	3												1	2	2	2
Wheat		2	2	2	2	2	2	3															1	2	2
Quinoa		2	2	2	2	2	2	2	2	2	3												1	2	2
Oats		2	2	2	2	2	2	2	2	3											1	2	2	2	2
Chocho		2	2	2	2	2	2	2	2	2	2	2	2	3										1	2
Carrots	1st				1	2	2	2	2	2	2	3													
	2nd					1	2	2	2	2	2	2	3												
	3rd						1	2	2	2	2	2	2	3											
	4th							1	2	2	2	2	2	2	3										
	5th												1	2	2	2	2	2	3						
	6th													1	2	2	2	2	2	3					
	7th														1	2	2	2	2	2	3				
	8th															1	2	2	2	2	2	3			
Beets						1	2	2	2	2	2	2	3	3	3										
Chard							1	2	2	2	2	2	2	3	3	3	3	3							
Radish	1st				1	2	3																		
	2nd					1	2	3																	
	3rd						1	2	3																
	4th							1	2	3															
	5th								1	2	3														
	6th									1	2	3													

Note: 1 denotes average planting season of crop. 2 denotes the time the crop is in the ground. 3 denotes the average harvest season

Table 40. Summary of Practiced Planting and Harvest Schedule for Field and Vegetable Crops in Cochas, Ecuador (continued)

Crop Name	Planting	Months of Year																							
		January		February		March		April		May		June		July		August		September		October		November		December	
Green Onion						1	2	2	2	2	2	2	3												
Onion	1st						1	2	2	2	2	2	2	2	3										
	2nd										1	2	2	2	2	2	2	2	3						
Brocolli	1st				1	2	2	2	2	3															
	2nd												1	2	2	2	2	3							
Cauliflower	1st				1	2	2	2	2	3															
	2nd												1	2	2	2	2	3							
Spinach	1st					1	2	2	2	2	2	3													
	2nd															1	2	2	2	2	2	3			
Lettuce					1	2	2	2	2	2	2	3													
Celery		1	2	2	2	2	2	2	3																
Turnip, Chinese														1	2	2	2	2	2	3					
Cabbage, Red	1st			1	2	2	2	2	2	3															
	2nd										1	2	2	2	2	2	3								
	3rd	3																		1	2	2	2	2	2
Cabbage, Green	1st			1	2	2	2	2	2	3															
	2nd										1	2	2	2	2	2	3								
	3rd	3																		1	2	2	2	2	2
Tomato				1	2	2	2	2	2	2	2	3													
Zucchini								1	2	2	2	2	3	3	3										

Note: 1 denotes average planting season of crop. 2 denotes the time the crop is in the ground. 3 denotes the average harvest season

Appendix C

Table 41. Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model

Nutrient	Measure	barley-Flour	barley-hulled-dry	beets-ckd	beets-fresh	broccoli-ckd	broccoli-fresh	carrots-fresh
Calories	kcal	345.00	354.00	37.19	43.00	35.00	34.00	43.10
Calories from Fat	kcal	14.40	20.70	0.00	1.53	3.69	3.33	1.71
Calories from SatFat	kcal	3.01	4.34	0.00	0.24	0.71	0.35	0.28
Protein	g	10.50	12.48	0.41	1.61	2.38	2.82	1.04
Carbohydrates	g	74.52	73.48	8.68	9.56	7.18	6.64	10.10
Dietary Fiber	g	10.10	17.30	1.24	2.80	3.30	2.60	3.00
Total Sugars	g	0.80	0.80	7.44	6.76	1.39	1.70	6.60
Fat	g	1.60	2.30	0.00	0.17	0.41	0.37	0.19
Saturated Fat	g	0.33	0.48	0.00	0.03	0.08	0.04	0.03
Mono Fat	g	0.20	0.29	0.00	0.03	0.04	0.01	0.01
Poly Fat	g	0.77	1.11	0.00	0.06	0.17	0.04	0.08
Trans Fatty Acid	g	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water	g	12.11	9.44	0.00	87.58	89.25	89.30	87.70
Vitamin A - IU	IU	0.00	22.00	0.00	33.00	1548.00	623.00	25359.00
Beta-Carotene	mcg	0.00	13.00	0.00	20.00	929.00	361.00	12320.00
Vitamin B1	mg	0.37	0.65	0.00	0.03	0.06	0.07	0.09
Vitamin B2	mg	0.11	0.28	0.00	0.04	0.12	0.12	0.06
Vitamin B6	mg	0.40	0.32	0.00	0.07	0.20	0.17	0.14
Vitamin B12	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin C	mg	0.00	0.00	0.00	4.90	64.90	89.20	6.99
Vitamin D	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin E	mg	0.57	0.57	0.00	0.04	1.45	0.78	0.42
Folate	mcg	8.00	19.00	0.00	109.00	108.00	63.00	13.30
Calcium	mg	32.00	33.00	0.00	16.00	40.00	47.00	27.00
Iron	mg	2.68	3.60	0.45	0.80	0.67	0.73	0.50
Potassium	mg	309.00	452.00	0.00	325.00	293.00	316.00	323.00
Sodium	mg	4.00	12.00	223.14	78.00	41.00	33.00	35.00
Zinc	mg	2.00	2.77	0.00	0.35	0.45	0.41	0.20
Omega 3 Fatty Acid	g	0.08	0.11	0.00	0.00	0.12	0.02	0.01
Omega 6 Fatty Acid	g	0.69	1.00	0.00	0.06	0.05	0.02	0.07

Table 42. **Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model** (continued)

Nutrient	Measure	carrots-ckd	cauliflower-ckd	cauliflower-fresh	celery-ckd	celery-fresh	chinese-turnip-ckd	chinese-turnip-fresh
Calories	kcal	41.00	32.00	31.00	18.00	16.00	17.00	14.00
Calories from Fat	kcal	2.16	2.79	2.70	1.44	1.53	2.16	0.90
Calories from SatFat	kcal	0.33	0.44	0.42	0.36	0.38	0.66	0.27
Protein	g	0.93	3.04	2.95	0.83	0.69	0.67	1.10
Carbohydrates	g	9.58	6.28	6.09	4.00	2.97	3.43	2.63
Dietary Fiber	g	2.80	3.30	3.13	1.60	1.39	1.60	1.40
Total Sugars	g	4.74	0.00	2.96	2.37	1.58	1.83	0.00
Fat	g	0.24	0.31	0.30	0.16	0.17	0.24	0.10
Saturated Fat	g	0.04	0.05	0.05	0.04	0.04	0.07	0.03
Mono Fat	g	0.01	0.03	0.03	0.03	0.03	0.04	0.02
Poly Fat	g	0.12	0.14	0.13	0.07	0.08	0.11	0.04
Trans Fatty Acid	g	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water	g	88.29	89.47	89.79	94.11	95.43	95.04	95.37
Vitamin A - IU	IU	16706.00	141.00	155.00	521.00	449.00	0.00	0.00
Beta-Carotene	mcg	8285.00	0.00	93.00	313.00	270.00	0.00	0.00
Vitamin B1	mg	0.07	0.07	0.08	0.04	0.02	0.00	0.03
Vitamin B2	mg	0.06	0.10	0.10	0.05	0.06	0.02	0.02
Vitamin B6	mg	0.14	0.21	0.22	0.09	0.07	0.04	0.07
Vitamin B12	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin C	mg	5.90	72.60	88.10	6.10	3.10	15.10	29.00
Vitamin D	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin E	mg	0.66	0.00	0.04	0.35	0.27	0.00	0.00
Folate	mcg	19.00	41.00	57.00	22.00	36.00	17.00	14.00
Calcium	mg	33.00	32.00	33.00	42.00	40.00	17.00	27.00
Iron	mg	0.30	0.72	0.73	0.42	0.20	0.15	0.80
Potassium	mg	320.00	278.00	300.00	284.00	260.00	285.00	280.00
Sodium	mg	69.00	23.00	23.00	91.00	80.00	249.00	16.00
Zinc	mg	0.24	0.63	0.64	0.14	0.13	0.13	0.13
Omega 3 Fatty Acid	g	0.00	0.11	0.10	0.00	0.00	0.07	0.03
Omega 6 Fatty Acid	g	0.11	0.03	0.03	0.07	0.08	0.04	0.02

Table 43. Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model (continued)

Nutrient	Measure	corn-ckd	corn-fresh	gn-cab-ckd	gn-cab-fresh	gn-onion-fresh	lettuce-fresh	oats	potato-ckd	quinoa-ckd
Calories	kcal	112.00	86.00	23.00	24.00	32.00	32.00	389.00	78.00	120.00
Calories from Fat	kcal	33.75	10.62	0.54	1.62	1.71	1.71	62.10	0.90	17.28
Calories from SatFat	kcal	14.43	1.64	0.00	0.21	0.29	0.29	10.95	0.23	0.00
Protein	g	8.82	3.22	1.27	1.21	1.83	1.83	16. 9	2.86	4.40
Carbohydrates	g	10.80	19.02	5.51	5.37	7.34	7.34	66.27	17.21	21.30
Dietary Fiber	g	2.30	2.70	1.90	2.30	2.60	2.60	10.60	3.30	2.80
Total Sugars	g	0.51	3.22	2.79	0.00	2.33	2.33	0.00	0.00	0.87
Fat	g	3.75	1.18	0.06	0.18	0.19	0.19	6.90	0.10	1.92
Saturated Fat	g	1.60	0.18	0.00	0.02	0.03	0.03	1.22	0.03	0.00
Mono Fat	g	1.50	0.35	0.02	0.01	0.03	0.03	2.18	0.00	0.00
Poly Fat	g	0.39	0.56	0.02	0.09	0.07	0.07	2.53	0.04	0.00
Trans Fatty Acid	g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water	g	76.03	75.96	92.57	92.52	89.83	89.83	8.22	77.80	71.61
Vitamin A - IU	IU	0.00	1.00	80.00	126.00	997.00	997.00	0.00	0.00	5.00
Beta-Carotene	mcg	0.00	1.00	48.00	0.00	598.00	598.00	0.00	0.00	0.00
Vitamin B1	mg	0.03	0.20	0.06	0.05	0.06	0.06	0.76	0.03	0.11
Vitamin B2	mg	0.11	0.06	0.04	0.03	0.08	0.08	0.14	0.04	0.11
Vitamin B6	mg	0.12	0.06	0.11	0.09	0.06	0.06	0.12	0.24	0.12
Vitamin B12	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin C	mg	0.00	6.80	37.50	42.00	18.80	18.80	0.00	5.20	0.00
Vitamin D	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin E	mg	0.00	0.07	0.14	0.00	0.55	0.55	0.00	0.00	0.63
Folate	mcg	9.00	46.00	30.00	57.00	64.00	64.00	56.00	10.00	42.00
Calcium	mg	22.00	2.00	48.00	47.00	72.00	72.00	54.00	45.00	17.00
Iron	mg	1.10	0.52	0.17	0.56	1.48	1.48	4.72	6.07	1.49
Potassium	mg	177.00	270.00	196.00	246.00	276.00	276.00	429.00	407.00	172.00
Sodium	mg	104.00	15.00	8.00	18.00	16.00	16.00	2.00	14.00	7.00
Zinc	mg	1.55	0.45	0.20	0.18	0.39	0.39	3.97	0.44	1.09
Omega 3 Fatty Acid	g	0.05	0.02	0.01	0.05	0.00	0.00	0.11	0.01	0.00
Omega 6 Fatty Acid	g	0.29	0.54	0.01	0.03	0.07	0.07	2.42	0.03	0.00

Table 44. Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model (continued)

Nutrient	Measure	radishes-fresh	rd-cab-ckd	rd-cab-fresh	spinach-ckd	spinach-fresh	tomato-fresh	wheat-flour	wheat-whl-grain
Calories	kcal	16.00	29.00	31.00	23.00	23.00	23.00	339.00	339.00
Calories from Fat	kcal	0.90	0.81	1.44	7.02	3.51	1.80	16.83	22.23
Calories from SatFat	kcal	0.29	0.10	0.19	0.00	0.57	0.25	2.90	4.09
Protein	g	0.68	1.51	1.43	2.98	2.86	1.20	13.70	13.68
Carbohydrates	g	3.40	6.94	7.37	2.71	3.63	5.10	72.57	71.13
Dietary Fiber	g	1.57	2.60	2.10	2.10	2.20	1.10	12.20	13.00
Total Sugars	g	1.83	3.32	3.83	0.00	0.42	4.00	0.41	0.00
Fat	g	0.10	0.09	0.16	0.78	0.39	0.20	1.87	2.47
Saturated Fat	g	0.03	0.01	0.02	0.00	0.06	0.03	0.32	0.45
Mono Fat	g	0.02	0.01	0.01	0.00	0.01	0.03	0.23	0.34
Poly Fat	g	0.05	0.04	0.08	0.00	0.16	0.08	0.78	0.98
Trans Fatty Acid	g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water	g	95.27	90.84	90.39	92.50	91.40	93.00	10.27	10.94
Vitamin A - IU	IU	7.00	33.00	1116.00	1158.00	9377.00	642.00	9.00	0.00
Beta Ca otene	mcg	4.00	20.00	670.00	0.00	5626.00	346.00	5.00	0.00
Vitamin B1	mg	0.01	0.07	0.06	0.11	0.08	0.06	0.45	0.42
Vitamin B2	mg	0.04	0.06	0.07	0.13	0.19	0.04	0.22	0.12
Vitamin B6	mg	0.07	0.22	0.21	0.09	0.19	0.08	0.34	0.42
Vitamin B12	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin C	mg	14.80	34.40	57.00	5.90	28.10	23.40	0.00	0.00
Vitamin D	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin E	mg	0.00	0.12	0.11	0.00	2.03	0.38	0.82	0.00
Folate	mcg	25.00	24.00	18.00	114.00	194.00	9.00	44.00	43.00
Calcium	mg	25.00	42.00	45.00	124.00	99.00	13.00	34.00	34.00
Iron	mg	0.34	0.66	0.80	1.48	2.71	0.51	3.88	3.52
Potassium	mg	233.00	262.00	243.00	256.00	558.00	204.00	405.00	431.00
Sodium	mg	39.00	28.00	27.00	55.00	79.00	13.00	5.00	2.00
Zinc	mg	0.28	0.25	0.22	0.30	0.53	0.07	2.93	4.16
Omega 3 Fatty Acid	g	0.03	0.02	0.04	0.00	0.14	0.00	0.04	0.05
Omega 6 Fatty Acid	g	0.02	0.02	0.03	0.00	0.03	0.08	0.74	0.93

Table 45. Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model (continued)

Nutrient	Measure	white-onion-fresh	zucchini-ckd	zucchini-fresh	chocho	rice	oil	brown-sugar	milk-cow	milk-goat	chicken
Calories	kcal	40.00	15.00	17.00	119.00	130.00	884.00	380.00	64.00	69.00	293.00
Calories from Fat	kcal	0.90	3.24	2.88	26.28	2.52	884.00	0.00	32.94	37.26	159.21
Calories from SatFat	kcal	0.38	0.65	0.76	3.11	0.69	69.82	0.00	20.50	24.00	34.07
Protein	g	1.10	1.14	1.21	15.57	2.69	0.00	0.12	3.28	3.56	15.78
Carbohydrates	g	9.34	2.69	3.11	9.88	28.17	0.00	98.09	4.65	4.45	17.00
Dietary Fiber	g	1.70	0.68	0.89	2.80	0.40	0.00	0.00	0.00	0.00	1.30
Total Sugars	g	4.24	2.01	2.22	0.00	0.05	0.00	97.02	4.65	4.45	0.41
Fat	g	0.10	0.36	0.32	2.92	0.28	100.00	0.00	3.66	4.14	17.69
Saturated Fat	g	0.04	0.07	0.08	0.35	0.08	7.76	0.00	2.28	2.67	3.79
Mono Fat	g	0.01	0.03	0.01	1.18	0.09	61. 5	0.00	1.06	1.11	6.79
Poly Fat	g	0.02	0.15	0.09	0.73	0.08	26.40	0.00	0.14	0.15	3.04
Trans Fatty Acid	g	0.00	0.00	0.00	0.00	0.00	1.77	0.00	0.11	0.00	0.00
Cholesterol	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	11.00	44.00
Water	g	89.11	95.22	94.79	71.08	68.44	0.00	1.34	87.69	87.03	47.76
Vitamin A - IU	IU	2.00	1117.00	200.00	7.00	0.00	0.00	0.00	138.00	198.00	0.00
Beta-Carotene	mcg	1.00	670.00	120.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00
Vitamin B1	mg	0.05	0.03	0.04	0.13	0.02	0.00	0.00	0.04	0.05	0.26
Vitamin B2	mg	0.03	0.02	0.09	0.05	0.01	0.00	0.00	0.16	0.14	0.08
Vitamin B6	mg	0.12	0.08	0.16	0.01	0.09	0.00	0.04	0.04	0.05	0.04
Vitamin B12	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.07	0.34
Vitamin C	mg	7.40	12.90	17.90	1.10	0.00	0.00	0.00	1.50	1.30	0.00
Vitamin D	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.20
Vitamin E	mg	0.02	0.12	0.12	0.00	0.04	17.46	0.00	0.00	0.07	0.40
Folate	mcg	19.00	28.00	24.00	59.00	3.00	0.00	1.00	5.00	1.00	8.00
Calcium	mg	23.00	18.00	16.00	51.00	10.00	0.00	83.00	119.00	134.00	18.00
Iron	mg	0.21	0.37	0.37	1.20	0.20	0.00	0.71	0.05	0.05	1.14
Potassium	mg	146.00	264.00	261.00	245.00	35.00	0.00	133.00	151.00	204.00	218.00
Sodium	mg	4.00	3.00	8.00	4.00	1.00	0.00	28.00	49.00	50.00	457.00
Zinc	mg	0.17	0.33	0.32	1.38	0.49	0.00	0.03	0.38	0.30	0.77
Omega 3 Fatty Acid	g	0.00	0.09	0.06	0.13	0.01	7.63	0.00	0.05	0.04	0.08
Omega 6 Fatty Acid	g	0.01	0.06	0.03	0.60	0.06	18.76	0.00	0.08	0.11	2.96

Table 46. Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model (continued)

Nutrient	Measure	pig	lamb	cuy	beef-cuts	beef-ground	eggs	pineapple	apple	peach	banana	salt	pepper	water
Calories	kcal	165.00	294.00	197.00	305.00	277.00	143.00	45.00	52.00	39.00	89.00	0.00	255.00	0.00
Calories from Fat	kcal	69.30	188.46	73.00	193.86	163.89	89.46	1.17	1.53	2.25	2.97	0.00	29.34	0.00
Calories from SatFat	kcal	23.62	79.47	0.00	76.86	63.40	27.90	0.00	0.25	0.17	1.01	0.00	8.82	0.00
Protein	g	22. 0	24. 2	29. 0	25. 4	26.28	12. 7	0.55	0.26	0.91	1.09	0.00	10.95	0.00
Carbohydrates	g	0.50	0.00	0.00	0.00	0.00	0.78	11.82	13.81	9.54	22.84	0.00	64.81	0.00
Dietary Fiber	g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	1.45	2.60	0.00	26.50	0.00
Total Sugars	g	0.00	0.00	0.00	0.00	0.00	0.77	8.29	10.39	8.09	12.23	0.00	0.64	0.00
Fat	g	7.70	20.94	8.00	21.54	18.21	9.94	0.13	0.17	0.25	0.33	0.00	3.26	0.00
Saturated Fat	g	2.62	8.83	2.00	8.54	7.04	3.10	0.00	0.03	0.02	0.11	0.00	0.98	0.00
Mono Fat	g	3.76	8.82	0.00	9.22	8.37	3.81	0.00	0.01	0.07	0.03	0.00	1.01	0.00
Poly Fat	g	1.08	1.51	0.00	0.78	0.51	1.36	0.00	0.05	0.09	0.07	0.00	1.13	0.00
Trans Fatty Acid	g	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	mg	57.00	97.00	82.00	88.00	89.00	423.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water	g	65.80	53.72	0.00	51.43	54.50	75.84	87.24	85.56	88.87	74.91	0.20	10.51	100.00
Vitamin A - IU	IU	0.00	0.00	0.00	0.00	0.00	487.00	52.00	54.00	326.00	64.00	0.00	299.00	0.00
Beta-Carotene	mcg	0.00	0.00	0.00	0.00	0.00	10.00	31.00	27.00	162.00	26.00	0.00	156.00	0.00
Vitamin B1	mg	0.74	0.10	0.00	0.08	0.05	0.07	0.08	0.02	0.02	0.03	0.00	0.11	0.00
Vitamin B2	mg	0.28	0.25	0.00	0.21	0.19	0.48	0.03	0.03	0.03	0.07	0.00	0.24	0.00
Vitamin B6	mg	0.35	0.13	0.00	0.33	0.43	0.14	0.11	0.04	0.02	0.37	0.00	0.34	0.00
Vitamin B12	mcg	0.68	2.55	0.00	2.44	2.94	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin C	mg	0.00	0.00	0.00	0.00	0.00	0.00	16.90	4.60	6.60	8.70	0.00	21.00	0.00
Vitamin D	mcg	0.80	0.10	0.00	0.00	0.20	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin E	mg	0.28	0.14	0.00	0.20	0.48	0.97	0.00	0.18	0.73	0.10	0.00	0.72	0.00
Folate	mcg	3.00	18.00	0.00	7.00	12.00	47.00	11.00	3.00	4.00	20.00	0.00	10.00	0.00
Calcium	mg	8.00	17.00	20.00	10.00	34.00	53.00	13.00	6.00	6.00	5.00	24.00	437.00	0.00
Iron	mg	1.40	1.88	2.34	2.62	2.63	1.83	0.25	0.12	0.25	0.26	0.33	28.86	0.00
Potassium	mg	362.00	310.00	0.00	313.00	354.00	134.00	125.00	107.00	190.00	358.00	8.00	1259.00	0.00
Sodium	mg	969.00	72.00	47.00	62.00	93.00	140.00	1.00	1.00	0.00	1.00	38758.00	44.00	0.00
Zinc	mg	2.63	4.46	0.00	5.85	6.17	1.11	0.08	0.04	0.17	0.15	0.10	1.42	0.00
Omega 3 Fatty Acid	g	0.17	0.30	0.00	0.22	0.05	0.07	0.00	0.01	0.00	0.03	0.00	0.16	0.00
Omega 6 Fatty Acid	g	0.90	1.21	0.00	0.56	0.44	1.29	0.00	0.04	0.08	0.05	0.00	0.97	0.00

Table 47. Summary of Nutrient Content Provided By 100 Grams of All Foodstuffs Utilized for Selection in Model (continued)

Nutrient	Measure	corn-flour	chard	tostada	white-onion-ckd	quinoa-dry	bread
Calories	kcal	361.00	19.00	332.32	23.00	368.00	325.14
Calories from Fat	kcal	34.74	1.80	180.06	6.30	54.63	170.93
Calories from SatFat	kcal	4.89	0.27	49.57	0.93	6.35	48.73
Protein	g	6.93	1.80	4.55	1.50	14. 2	6.15
Carbohydrates	g	76.85	3.74	34.58	3.27	64.16	33.54
Dietary Fiber	g	7.30	1.60	3.28	0.30	7.00	4.53
Total Sugars	g	0.64	1.10	0.38	1.33	4.94	0.45
Fat	g	3.86	0.20	20.32	0.70	6.07	19.30
Saturated Fat	g	0.54	0.03	5.51	0.10	0.71	5.41
Mono Fat	g	1.02	0.04	9.31	0.30	1.61	8.95
Poly Fat	g	1.76	0.07	4.10	0.26	3.29	3.66
Trans Fatty Acid	g	0.00	0.00	0.39	0.00	0.00	0.39
Cholesterol	mg	0.00	0.00	63.06	0.00	0.00	63.06
Water	g	10.91	92.66	38.00	93.26	13.28	38.54
Vitamin A - IU	IU	214.00	6116.00	346.88	5.00	14.00	250.83
Beta-Carotene	mcg	97.00	3647.00	57.13	1.00	8.00	13.60
Vitamin B1	mg	0.25	0.04	0.12	0.01	0.36	0.17
Vitamin B2	mg	0.08	0.09	0.09	0.01	0.32	0.11
Vitamin B6	mg	0.37	0.10	0.18	0.02	0.49	0.19
Vitamin B12	mcg	0.00	0.00	0.15	0.00	0.00	0.15
Vitamin C	mg	0.00	30.00	0.00	0.50	0.00	0.00
Vitamin D	mcg	0.00	0.00	0.25	0.00	0.00	0.25
Vitamin E	mg	0.42	1.89	2.41	0.11	2.44	2.48
Folate	mcg	25.00	14.00	16.57	6.00	184.00	8.94
Calcium	mg	7.00	51.00	11.94	12.00	47.00	23.16
Iron	mg	2.38	1.80	1.27	0.27	4.57	1.41
Potassium	mg	315.00	379.00	158.01	28.00	563.00	155.32
Sodium	mg	5.00	213.00	709.62	423.00	5.00	709.17
Zinc	mg	1.73	0.36	0.91	0.25	3.10	1.03
Omega 3 Fatty Acid	g	0.05	0.01	0.90	0.02	0.31	0.91
Omega 6 Fatty Acid	g	1.71	0.06	3.20	0.24	2.99	2.75

Appendix D

Table 48. Recommended Dietary Allowances and Adequate Intakes of Nutrients, Vitamins, Minerals, and Trace Elements

	Protein (g/d)	Riboflavin (mg/d)	Sodium (g/d)	Sugars -	Thiamin (mg/d)	Vit (ug/d)	Vit B12 (g/d)	Vit B6 (mg/d)	Vit C (mg/d)
Infants									
0-6	9.1	0.3	0.12	ND	0.2	400	0.4	0.1	40
7-12	**11**	0.4	0.37	ND	0.3	500	0.5	0.3	50
Children									
1–3	**13**	**0.5**	1	ND	**0.5**	**300**	**0.9**	**0.5**	**15**
4–8	**19**	**0.6**	1.2	ND	**0.6**	**400**	**1.5**	**0.6**	**25**
Males									
9–13	**34**	**0.9**	1.5	ND	**0.9**	**600**	**1.8**	**1**	**45**
14–18	**52**	**1.3**	1.5	ND	**1.2**	**900**	**2.4**	**1.3**	**75**
19–30	**56**	**1.3**	1.5	ND	**1.2**	**900**	**2.4**	**1.3**	**90**
31–50	**56**	**1.3**	1.5	ND	**1.2**	**900**	**2.4**	**1.3**	**90**
51–70	**56**	**1.3**	1.3	ND	**1.2**	**900**	**2.4**	**1.7**	**90**
>70	**56**	**1.3**	1.2	ND	**1.2**	**900**	**2.4**	**1.7**	**90**
Females									
9–13	**34**	**0.9**	1.5	ND	**0.9**	**600**	**1.8**	**1**	**45**
14–18	**46**	**1**	1.5	ND	**1**	**700**	**2.4**	**1.2**	**65**
19–30	**46**	**1.1**	1.5	ND	**1.1**	**700**	**2.4**	**1.3**	**75**
31–50	**46**	**1.1**	1.5	ND	**1.1**	**700**	**2.4**	**1.3**	**75**
51–70	**46**	**1.1**	1.3	ND	**1.1**	**700**	**2.4**	**1.5**	**75**
> 70	**46**	**1.1**	1.2	ND	**1.1**	**700**	**2.4**	**1.5**	**75**
Pregnancy									
14–18	**71**	**1.4**	1.5	ND	**1.4**	**750**	**2.6**	**1.9**	**80**
19–30	**71**	**1.4**	1.5	ND	**1.4**	**770**	**2.6**	**1.9**	**85**
31–50	**71**	**1.4**	1.5	ND	**1.4**	**770**	**2.6**	**1.9**	**85**
Lactation									
14–18	**71**	**1.6**	1.5	ND	**1.4**	**1200**	**2.8**	**2**	**115**
19–30	**71**	**1.6**	1.5	ND	**1.4**	**1300**	**2.8**	**2**	**120**
31–50	**71**	**1.6**	1.5	ND	**1.4**	**1300**	**2.8**	**2**	**120**

Note: This summary table is composed of multiple Dietary Reference Intake reports taken from www.nap.edu and presents Recommended Dietary Allowances (RDAs) in **bold type** and Adequate Intakes (AIs) in ordinary type.

Table 49. Recommended Dietary Allowances and Adequate Intakes of Nutrients, Vitamins, Minerals, and Trace Elements (continued)

	Calcium (mg/d)	Calories (cal/d)	Carbohydrate (g/d)	Cholesterol -	Fat (g/d)	Fiber (g/d)	Folate (g/d)	Iron (mg/d)	Niacin (mg/d)
Infants									
0-6	200	ND	60	ND	31	ND	65	0.27	2
7-12	260	ND	95	ND	30	ND	80	**11**	4
Children									
1–3	**700**	1000	**130**	ND	ND	19	**150**	**7**	**6**
4–8	**1000**	1200	**130**	ND	ND	25	**200**	**10**	**8**
Males									
9–13	**1,300**	1800	**130**	ND	ND	31	**300**	**8**	**12**
14–18	**1,300**	2200	**130**	ND	ND	38	**400**	**11**	**16**
19–30	**1000**	2400	**130**	ND	ND	38	**400**	**8**	**16**
31–50	**1000**	2200	**130**	ND	ND	38	**400**	**8**	**16**
51–70	**1000**	2000	**130**	ND	ND	30	**400**	**8**	**16**
>70	**1,200**	2000	**130**	ND	ND	30	**400**	**8**	**16**
Females									
9–13	**1,300**	1600	**130**	ND	ND	26	**300**	**8**	**12**
14–18	**1,300**	1800	**130**	ND	ND	26	**400**	**15**	**14**
19–30	**1000**	2000	**130**	ND	ND	25	**400**	**18**	**14**
31–50	**1000**	1800	**130**	ND	ND	25	**400**	**18**	**14**
51–70	**1,200**	1600	**130**	ND	ND	21	**400**	**8**	**14**
> 70	**1,200**	1600	**130**	ND	ND	21	**400**	**8**	**14**
Pregnancy									
14–18	**1,300**	ND	**175**	ND	ND	28	**600**	**27**	**18**
19–30	**1000**	ND	**175**	ND	ND	28	**600**	**27**	**18**
31–50	**1000**	ND	**175**	ND	ND	28	**600**	**27**	**18**
Lactation									
14–18	**1,300**	ND	**210**	ND	ND	29	**500**	**10**	**17**
19–30	**1000**	ND	**210**	ND	ND	29	**500**	**9**	**17**
31–50	**1000**	ND	**210**	ND	ND	29	**500**	**9**	**17**

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Appendix E

Table 50. Yearly RDA Values for Nutrients, Vitamins, Minerals, Trace Elements for a Family of Six in Cochas, Ecuador

Life stage	Age	Calories (cal/d)	Fat (g/d)	Sodium (g/d)	Carbohydrates (g/d)	Fiber (g/d)	Protein (g/d)	VitA (ug/d)	VitC (mg/d)	Calcium (mg/d)	Iron (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)
mother, pregnant	29	60000	0	45	5250	840	2130	23100	2400	30000	810	1.4	18
father	32	66000	0	45	3900	1140	1680	27000	2700	30000	240	16	16
daughter	10	48000	0	45	3900	780	1020	18000	1350	39000	240	0.9	12
son	6	36000	0	36	3900	750	570	12000	750	30000	300	0.6	8
daughter	2	30000	0	30	3900	570	390	9000	450	21000	210	0.5	6
grandma	59	48000	0	36	3900	630	1380	21000	2250	36000	240	1.1	14
Total		288000	0	237	24750	4710	7170	110100	9900	186000	2040	20.5	74

Appendix F

EXAMPLE OF SURVEY

Financial

¿Qué tipo de trabajo que has hecho en el pasado fuera de la granja para ganar dinero?

¿Qué tipo de trabajo podría hacer ahora, si usted no trabajó en la granja?

¿Cuál es el sueldo por un trabajo como ese?

¿Se puede ganar este mismo sueldo todo el año osea cada mes?

¿Podría usted trabaja durante todo el año haciendo eso?

¿Cuánto es el costo de traer a alguien para ayudar en la granja?

qué tipo de trabajo iban a hacer esta ayudante?

El ayudante trabaja tan bien y tan rápido como usted? Son las semillas, fertilizantes, herramientas, o el agua en el crédito?

¿pide usted o alguien en la casa prestado dinero para la preparación, siembra, o mantener el cultivo?

¿Es usted pide prestado dinero para vivir mientras espera a que el cultivo esté listo para la cosecha?

¿Cuánto cuesta la inscripción escolar para cada niño?

¿Cuánto cuestan los uniformes?

¿Cuánto cuestan los libros y otros insumos?

¿Cuánto cuesta el almuerzo?

¿Cuánto gasta al mes / año en el médico?

Por miembro de la familia

lo que ha ocurrido para que usted o un miembro de la familia a tener que ver a un médico?

¿Cuánto cuesta cada visita al médico?

¿cuánto es una receta?

Crop

¿Qué cultivos se siembran?

Jan	Feb	Mar	Apr
	May	Jun	Jul
Aug	Sep	Oct	Nov
	Dec		

¿Por qué decidió a sembrar este cultivo en lugar de otros?

¿Considera usted que los beneficios nutricionales del cultivo?

¿Son los precios de mercado un factor en la selección de cultivos?

¿Cree usted que de lo que tendría que pagar en el mercado para comer si no plantar este cultivo?

¿Cuándo fue este cultivo sembrado / plantado puede ser?

Jan	Feb	Mar	Apr
	May	Jun	Jul
Aug	Sep	Oct	Nov
	Dec		

¿Alguna vez ha tratado de sembrar temprano o más tarde?

¿Se preparó la tierra para la siembra por ti mismo?

¿Quién le ayudó?

¿Cuánto tiempo cada uno de ustedes trabajar en la preparación del terreno?

¿cada uno de ustedes completar la misma cantidad de trabajo en una hora? Si no es así, ¿cuál es la relación?

¿Qué le haría más fácil para preparar el suelo o hacer que vaya más rápido?

¿Qué herramientas se utilizan para plantar la cosecha?

¿Cuánto tiempo para cada herramienta?

¿Hay algo que haría que la preparación de la tierra para la siembra de más fácil o más rápido?

¿Qué insumos se necesitan para plantar la cosecha?

cuesta?

agua

¿Qué herramientas se utilizaron?

¿De cuánto tiempo fue dedicado al uso de cada una de las herramientas para plantar la cosecha?

¿Hizo usted plantar la cosecha de si mismo?

¿Quién le ayudó?

¿Cuánto tiempo cada uno de ustedes trabajar en la plantación?

¿Qué podría hacer la plantación ir más rápido o más fácil?

costos asociados?

Una vez que se sembró el cultivo, el tiempo de cuánto se gasta por día o semana el mantenimiento de la cosecha?
Deshierbe

Riego

Difusión de los Fertilizantes

Otro

¿Usa los pesticidas?

¿Cuánto?

¿Cuánto tiempo se necesita para aplicarlo?

¿Qué se utiliza para aplicarla?

¿De dónde obtiene el agua necesaria para su cultivo?

¿Tiene algún costo? ¿Cuánto? Los derechos de agua?
¿Con qué frecuencia regar el cultivo?

¿Cuánta agua se utiliza cada vez? Cantidad o tiempo?

¿Qué herramientas o suministros se necesitan para obtener el agua para su cultivo?

¿Cuándo es la cosecha?

una cosecha?

¿Cuál es el rendimiento de este cultivo?

¿qué crees que afecta el rendimiento de la mayoría?
el agua?
los fertilizantes?

¿se almacena alguna de la cosecha?

¿Por qué no?
¿Cómo se almacena?

¿Cuánto se pierde al mez?

Debido a la descomposición / las ratas?

cuánto tiempo hace que el almacenamiento de alimentos les perdura?

¿Cuánta tierra se utiliza para sembrar este cultivo?

Groceries

24-hora recordatorio de alimentos

Entre comidas

¿Cuál es su lista de compras típico?

¿Cuál es su presupuesto semanal / mensual de los alimentos?

Oxen

¿Es usted dueño del buey?

¿Cuánto fue el buey?

¿Se arriende el buey a los demás?

¿Cuál es el cargo?

¿Cuánto cuesta pedir prestado?

¿Por cuánto tiempo tomarlo prestado por?

¿Qué edad tiene el animal?

¿Que le da al buey de alimento?

¿Cree usted que sería saludable si usted le dio más de buey para comer?

¿Cultiva la alimentación? ¿Cuánto de ello?

¿Qué cantidad de tierra que se necesita para la que se alimentan?

¿A cuánto cuesta las facturas del veterinario de ano?

¿Qué otros cobras se incurre al tener el buey?

los derechos de pastoreo?

¿Cuántos años es un buey para el arado buena?
¿Qué se hace con ella después de que se es demasiado viejo?

¿Cuánto es el arnés?

¿Cuánto es el arado?

¿Cuántos años son el arnés y el arado bueno?

¿Qué tipo de reparaciones son necesarias en el arado o el arnés?

¿Cuánto cuesta este costo promedio por temporada / cultivos / año?

¿Por qué no utilizar un tractor?

Tractor

¿Es usted dueño del tractor?
¿Cuánto fue el tractor?
¿Cuanto les pide a los vecinos para arrendar al tractor?

¿Cuánto cuesta pedir prestado?

¿Por cuánto tiempo tomarlo prestado por?

¿Qué edad tiene el tractor?

¿Cuántos años le sirve un tractor para arar?

¿Qué se hace con el tractor después de que es demasiado viejo?

¿Cuánto es el arnés?

¿Cuánto es el arado?

¿Cuántos años son el arnés y el arado bueno para utilizar?

¿Qué tipo de reparaciones o mantenimiento que se necesita el tractor cada mes / temporada / año?

¿cuánto cuesta esto?

¿Qué tipo de reparaciones son necesarias del arado o el arnés?

¿Cuánto cuesta este costo promedio por temporada / cultivos / año?

¿Cuánto gasta de combustible por mes / temporada / año?

¿Por qué no utilizar un buey?

Water

Lo que afecta el suministro de agua?

¿Cuáles son las interrupciones?

¿Qué hacer cuando no podía conseguir agua cuando sea necesario para regar el cultivo?

¿Qué meses normalmente tienen suficiente lluvia para los cultivos?

Jan Feb Mar Apr May Jun Jul Aug

Sep Oct Nov Dec

¿Qué meses no tienen suficiente lluvia para los cultivos?

Jan Feb Mar Apr May Jun Jul Aug

Sep Oct Nov Dec

¿Ha notado la pauta de las precipitaciones está cambiando?
¿Cómo?

Es la temporada de lluvias empezando mas tarde? Es la temporada de lluvias terminando más tarde?
¿Como cree usted que es la lluvia más o menos en comparación con hace 5 años?

¿Es posible utilizar el agua del llave para regar los cultivos?

¿Has pensado en formas de almacenar el agua de lluvia?

¿Ha tratado de almacenar agua para la temporada seca?

Incluso si usted tenía un poco de agua almacenada, ¿crees que se podría almacenar agua suficiente para superar el suelo seco y el sol caliente?

¿Crees que tus cultivos sería mejor si tuviera alguna fuente de agua que se puede utilizar para regar sus cultivos sobre una base regular en lugar de depender de la lluvia?

Chicken

¿Tiene alguna gallina?

¿cuántos?

¿Cuánto cuesta comprar?

¿Qué edad tenían?

¿Qué les das de comer a las gallinas?

¿Cuántos huevos se puede conseguir de un día / mes?

Hay meses cuando las gallinas se les dan mas huevos? Cuales son?

Cuantos?

¿Cuánto tiempo espera antes de comer las gallinas?

¿Dónde los guarda?

¿Cuánto fue el recinto?

¿De cuánto tiempo se necesita para reparar la caja por mes / año?

¿Con qué frecuencia se muere o ser comido por otro animal?

Cuy

¿Tiene algún cuy?

¿cuántos?

¿Cuánto cuesta comprar?

¿Qué edad tenían al comprarlo?

¿Qué les das de comer?

¿Cuánto tiempo espera antes de comerlas?

¿Dónde las guarda?

¿Cuánto fue el recinto?

¿De cuánto tiempo se necesita para reparar la caja por mes / año?

¿Con qué frecuencia se muere o ser comido por otro animal?

¿Cuánta carne tiene uno?

Dairy Goat

¿Tiene algún cabras?

¿cuántos?

¿Cuánto cuesta comprar?

¿Qué edad tenían?

¿Qué les das de comer?

¿Cuándo empiezan a lactantes?

la cantidad de leche se puede conseguir cada mes dia?

cuales son los mejores meses

peores meses

¿Cuánto tiempo espera antes de comerlas?

¿Dónde los guarda?

¿Cuánto fue el recinto?

¿De cuánto tiempo se necesita para reparar el recinto por mes / año?

¿Con qué frecuencia uno morir / ser comido por otro animal?

Pig

¿Tiene usted un cerdo?

¿cuántos?

¿Cuánto cuesta cada cerdo para comprar?

¿Qué edad tiene el cerdo normalmente cuando usted lo compra?

¿Qué les das de comer?

¿Qué edad tienen cuando se los comen?

¿Qué edad tienen cuando se llevan al mercado a vender? A cuanto se lo venden?

¿Dónde los guarda?

¿Cuánto fue el recinto?

¿De cuánto tiempo se necesita para reparar el recinto por mes / año?

¿Con qué frecuencia uno morir / ser comido por otro animal?

Cow

¿Tiene algún vacas?

¿cuántos?

¿Cuánto cuesta comprar?

¿Qué edad tenían?

¿Qué les das de comer?

¿Cuándo empiezan a lactantes?

la cantidad de leche se puede conseguir cada mes / día?

mejores meses/ día peores meses o día

¿Qué edad tienen cuando se llevan al mercado a vender? A cuanto se lo venden?

Si usted va a comer a la vaca, ¿cuánto tiempo se mantendrá antes de comerlas? Sabe la cantidad de carne se puede conseguir de una vaca?

¿Dónde los guarda?

¿Cuánto fue el recinto?

¿De cuánto tiempo se necesita para reparar el recinto por mes / año?

¿Con qué frecuencia uno morir / ser comido por otro animal?